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WIRELESS TELEPHONY.*

BY

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FUNDAMENTAL REQUIREMENTS.

THE development of wireless telephony dates back almost as far as the original conception of the use of electromagnetic waves for wireless telegraphy. The practical utilization of this method of communication is, however, a matter of comparatively recent date as contrasted with the much longer period during which wireless telegraphy has been a practical accomplishment. This delay in the successful utilization of wireless telephony is due to certain differences in the fundamental requirements as compared with those for the telegraph. These differences and the manner in which the particular difficulties incident to the successful accomplishment of wireless telephony have been overcome will be explained in detail in succeeding paragraphs.

Broadly speaking, the principal difference between wireless telephony and wireless telegraphy lies in the form of the signal which has to be transmitted, telegraph signals being obviously far simpler in the wave-form of the signal current than are telephone signals. The fundamental requirement is, in either case,

* Presented at a joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, October 30, 1919.

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that the form of the receiving signal shall faithfully reproduce the form of the transmitted signal, whether due to the opening and closing of a telegraph key or the vibrations of a telephone transmitter diaphragm.

The essential units required in a complete wireless telephone system may be grouped into the transmitting and the receiving elements. The receiving elements, being in no respect different from those required in wireless telegraphy, will not be described at this point. The transmitting elements differ, however, in many respects and comprise the following essential units:

A radio frequency generator.

A modulator for controlling the radio frequency current.

An antenna for radiating the electromagnetic waves produced by the radio frequency current.

The particular characteristics of these various units are described in detail hereinafter.

Wireless telephony is subject to certain particular limitations in the same way as wireless telegraphy, notably that of interference due to atmospheric electricity or radio signals foreign to the desired signal.

HISTORICAL SUMMARY.

The first requirement for any wireless telephone station is a source of radio frequency current whose amplitude from cycle to cycle remains constant, except when varied by the modulation imposed upon it by the voice current. If variations in its amplitude occur, due to other causes, these variations will introduce disturbances which will cause the system to be deficient in the effective transmission of speech. It is at once evident that the original source of radio frequency current used in wireless telegraphy, namely, the oscillatory discharge of a condenser supplied with energy from a low frequency source, is entirely unsuited to the purposes of wireless telephony.

With the development of the Poulsen arc the first successful attempts at radio telephony were begun. These attempts involved the second factor in a wireless telephone station, namely, that of modulating the radio frequency current in accordance with the currents supplied by a telephone transmitter. The early attempts to accomplish this modulation, by means of microphones inserted

directly in the antenna circuit or coupled to the circuit in various manners, were largely unsuccessful due to the limitations of the microphone devices, such as the low current capacity and the small range of variation of resistance.

A second source of radio frequency current is the high frequency alternator, which has been developed in various forms and which has been likewise used with limited success for wireless telephone transmission. The same lack of a suitable modulating device handicapped the use of the high frequency alternator until the advent of the audion or vacuum tube. The characteristics of the vacuum tube have been fully described in many recent publications, and will be discussed in this paper only in so far as these characteristics are directly applicable to the problems of wireless telephony. It will be seen from this subsequent discussion that the vacuum tube possesses in a remarkable manner the precise characteristics required for the generation and modulation of radio frequency current for low power wireless telephone stations, and for the detection and amplification of radio signals of any character whatsoever. Its influence on the art of wireless telephony may well be compared with the influence of the gas engine on aviation.

VACUUM TUBE.

The requirements of a radio frequency generator may be grouped as follows:

The desired frequency may range roughly between the values of 15,000 and 6,000,000 cycles per second.

The frequency for any particular generator may be required to vary over a considerable range, in some cases as much as several octaves. In other cases, a single value of frequency is sufficient.

The frequency when set at a particular value should remain substantially unaffected by ordinary changes in the physical or electrical conditions associated with the station.

The current delivered by the generator should approximate a sine wave as closely as possible.

The required output for different classes of stations may vary from less than one watt to several hundred kilowatts.

The efficiency of the generator should be reasonably high though not necessarily comparable with the efficiencies obtained from ordinary types of generators.

When used as an oscillator or radio frequency generator associated with properly designed circuits, the vacuum tube will meet all of these requirements, with the exception that the power output of vacuum tubes as at present constructed is limited to not more than a few hundred watts per tube.

The requirements of a modulator for radio telephony may be grouped as follows:

The modulator should be actuated by the current from an ordinary microphone telephone transmitter or its equivalent.

The modulator should faithfully reproduce, in its effect upon the radio frequency current, the wave-form of the telephone or speech current.

The modulator should be capable of almost completely modulating the output of radio frequency generators whose power outputs may cover the range indicated above.

These requirements are fulfilled to a remarkable extent by the vacuum tube used in properly designed circuits.

Although the vacuum tube was invented in 1906, its development into a sufficiently practical form to be useful for wireless telephony was comparatively slow. This development was greatly accelerated, beginning in 1912, when the American Telephone and Telegraph Company became interested in the vacuum tube for use in telephone repeaters. Rapid improvements were made in the design and construction of vacuum tubes, and at the same time experiments were conducted looking to the use of the vacuum tube in wireless telephone apparatus. As a result of these experiments, the transmission of speech from Washington, D. C., to Paris and to Honolulu by wireless telephone occurred during the year 1915. In these experiments the vacuum tube was used as a radio frequency generator, a modulator, a detector and amplifier.

The possibilities of the vacuum tube for wireless telephony having been partly disclosed by the above experiments, the Navy Department became actively interested in the development of wireless telephone apparatus for use on battleships. Experimental sets were developed by the Western Electric Company and

extremely promising results were secured. The Signal Corps was likewise interested in the development of apparatus for the Army, but experiments had not proceeded to the point where any satisfactory apparatus had been developed prior to the declaration of war by this country.

FIELD OF MILITARY APPLICATION.

Prior to the beginning of the European War the use of wireless telegraphy in military operations had been limited to an extremely narrow field, while wireless telephony had been used to an entirely negligible extent. The communication requirements for the armies engaged in the trench-warfare style of conflict emphasized the need of radio communication, and accordingly the extent and variety of the apparatus for wireless telegraphy increased rapidly. At the time this country entered the war wireless telegraphy comprised an extremely important and extensive part of the communication systems employed on the western front. The development of wireless telephony, however, had not proceeded to the point where satisfactory apparatus was available for use by the military forces. The particular field which most urgently required its use was the airplane communication system. The limitations imposed on the use of wireless telephony, such as greater weight and complication of the apparatus, and complete lack of secrecy, had hitherto prevented favorable consideration of wireless telephony as a substitute for wireless telegraphy. The particular requirements of the airplane communication, however, introduced certain advantages which more than compensated for these factors and made telephony much more desirable than telegraphy. The controlling reason for the use of the wireless telephone lay in the fact that its use eliminated the necessity of a knowledge of the telegraph code on the part of the aviator. An additional advantage lay in the greater speed with which the telephone transmission can be effected.

Inasmuch as the airplane wireless telephone set comprises not only the most interesting example of the use of wireless communication during the war, but furnishes also a remarkable example of the rapidity with which the engineering and manufacturing facilities of this country were adapted to war-time needs, a detailed summary of the development, production and operation of

this set forms an important part of the general subject of wireless telephony.

HISTORICAL REVIEW.

Almost immediately following the declaration of war by this country, the Chief Signal Officer of the Army issued orders for the development of an airplane wireless telephone set which was to furnish telephone communication between the different airplanes of a squadron and also to furnish communication between an airplane and a ground station. The fundamental requirements for this set were based partly on information furnished by the Allies, and partly on the experience of the U. S. Signal Corps in the pre-war experiments in airplane radio telegraphy and telephony. The actual development work was entrusted to the Engineering Department of the Western Electric Company, with provision for the necessary airplane facilities and information to be supplied by the Signal Corps as required. The progress of the development work was extremely rapid, successful communication being established between an airplane and a ground station within six weeks from the date the development was started. The evolution of a complete design suited to commercial production likewise proceeded very rapidly, so that by December, 1917, only six months from the time the development work was started, the design of the complete equipment had reached the stage where production of the sets in quantity could be authorized. As early as October, 1917, the apparatus had been developed to a sufficiently complete extent to warrant sending samples to the Expeditionary Forces for test under conditions existing at the front.

Because of the extreme need for the earliest possible delivery of apparatus in large quantities, to meet the needs of the airplane program of the United States, the production of airplane telephone sets was begun prior to the completion of the experimental work. As further experiments indicated the need of modification or refinements in the design, the necessary changes were incorporated in the process of manufacture, so that the sets delivered in the spring of 1918 embodied the results of experimental work extending almost up to the date of completion of the sets.

Beginning early in the summer of 1918 the development of an improved type of set was begun, and at the time of the armistice this development had reached the point where practical trials of

the completed sets were in progress. The essential differences between the original type of set and this new set are described in some detail in succeeding paragraphs.

The production of several thousand of the airplane wireless telephone sets in the brief space of a few months involved many problems of an extremely unusual and difficult nature. As an example may be cited the production of the vacuum tubes required for use in the sets. Prior to the war the vacuum tubes had never been produced at rates greater than a few hundred tubes per week. At the time of the armistice the production of these tubes in one factory alone was in excess of 25,000 per week, the largest part of which was intended for use with the airplane wireless telephone sets. The problem of devising methods for testing the completed sets involved the development of unusual testing facilities and the creation of a large organization of inspectors to handle the sets as rapidly as they were delivered from the factory. It was obviously impossible to test each completed set in an airplane before considering it as finally accepted, so that the formulation of the testing specifications involved the development of tests which would approximate the conditions encountered on airplanes and at the same time would be adapted to factory methods of testing.

Before the development of the airplane wireless telephone sets had proceeded even to the point where success was assured, it became apparent to those involved in the work that the production of a satisfactory set was by no means the complete solution of the problem. The successful use of the equipment would undoubtedly require a considerable amount of training of the aviators and a very considerable period of experiment with the trained aviators using the equipment before its limitations and its possibilities could be even approximately determined. Accordingly preparations were made in advance of the delivery of the first production sets, to institute a course of training which was intended both to familiarize the aviator with the actual use of the set and to work out the method of use; in other words, the tactics of a voice-commanded airplane squadron. As early as May, 1918, groups of airplanes using the wireless telephone sets were being trained in the use of this equipment and were being drilled in the evolutions which the equipment made possible. In June, 1918, a squadron of 39 airplanes, equipped with wireless telephone

sets, went through a course of drill in the air in such a manner as to demonstrate the remarkable possibilities of a voice-commanded squadron. Subsequently the training of aviators in the tactics of "V. C." flying progressed at a rapidly increasing rate, so that at the time of the signing of the armistice many thousand flights had been made. The record of these flights is a glowing tribute to the efficiency of the design of the airplane wireless telephone sets, which performed in such a manner as to give far less trouble than the airplane engine.

AIRPLANE SETS.

At the outset of the war-time development work on the airplane wireless telephone apparatus the requirements which the apparatus would have to meet and the particular conditions under which it would operate were largely unknown; this information became apparent more or less gradually during the progress of the development work, which fortunately proceeded along such lines as to substantially comply with the requirements as they developed. As originally conceived, these requirements may be briefly stated as follows:

> The apparatus should be capable of effecting reliable telephone communication between two airplanes at distances up to 2000 yards.
>
> The weight of the apparatus should be the minimum possible consistent with meeting the range requirements and other conditions imposed on the operation.
>
> The apparatus should be of the simplest possible construction and should require the minimum amount of adjustment or manipulation by the aviator.

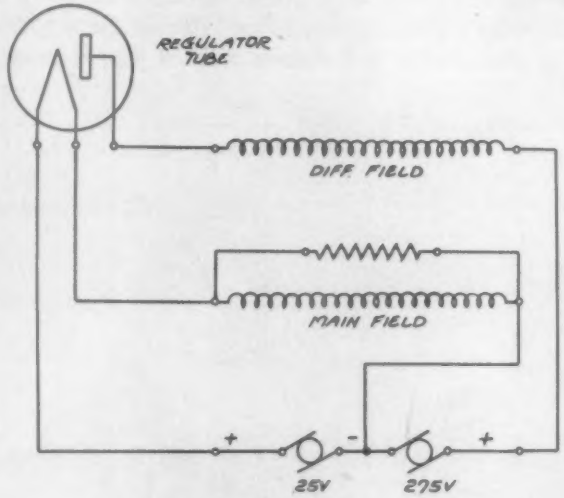
It was realized that special conditions would be encountered on the airplane which would make the development work extremely difficult and would require radical departures from any previous practice. Among these special conditions may be mentioned the tremendous noise and vibration created by the engine and wind, the necessity of reducing the fire hazard to a minimum, and, above all, the extremely essential condition that the wireless telephone apparatus must create the minimum possible interference with the various other functions of the aviator.

The various elements comprising the complete wireless telephone set may be grouped into the following units:

Power Plant.
Transmitting Unit.
Receiving Unit.
Antenna System.

The details of these various units and the problems encountered in their development are briefly described in the following paragraphs:

FIG. 1.



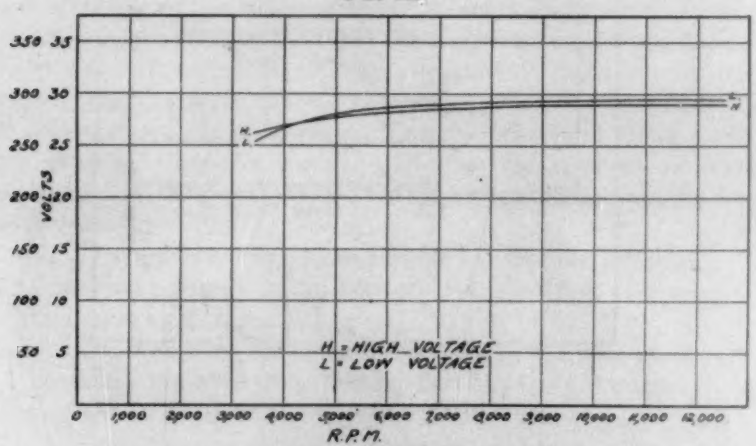
Circuit diagram, wind-driven generator.

POWER PLANT.

The preliminary experiments with various types of apparatus soon determined the power requirements of the apparatus which included power supply for the filament and plate circuits of the vacuum tubes for both transmitting and receiving circuits and power for the telephone transmitters. The filament power required was determined to be 1.35 amperes at 24 volts and the plate circuit power for the transmitting set .070 amperes at 275 volts. The plate current for the receiving tubes was extremely small, namely, less than .004 amperes, and it was decided to furnish this power from dry batteries. After various arrangements were tried the current for the telephone transmitter was obtained by shunting this transmitter about filaments of two vacuum tubes

which gave approximately the correct voltage for operating this transmitter. The 24-volt and 275-volt power is obtained from a double voltage direct current generator which is driven by an air fan, the complete generator being mounted on one of the struts of the landing gear of the airplane and hence being directly in the propeller blast. The most difficult problems involved in the design of the generator were those related to the excessive speed variation and the extremely high maximum speed at which the generator was required to operate. The air speed of the plane being subject to extremely wide variations and the air fan rotational speed varying in almost exactly the same ratio, it was necessary for the

FIG. 1a.



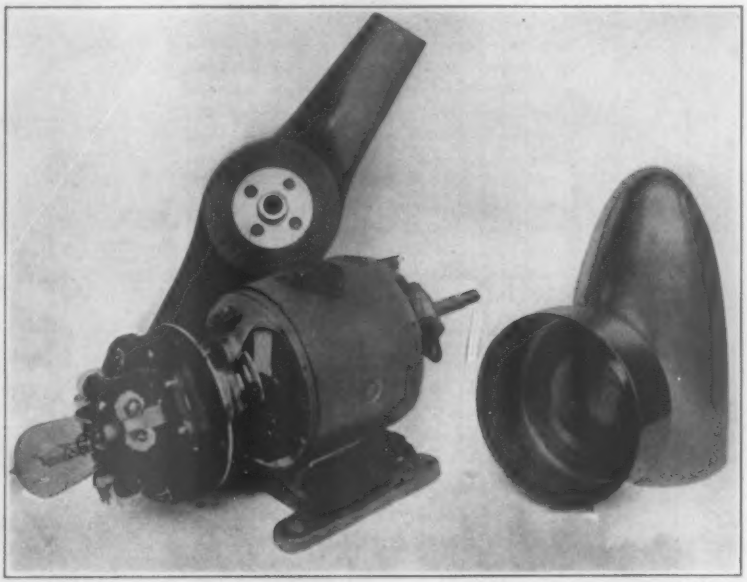
Voltage characteristic, wind-driven generator.

generator to furnish its normal voltages over a speed range of 4000 to 12,000 r. p. m. This required the use of a special voltage regulator, the circuits of which are shown in Fig. 1. This regulator depends for its operation upon the relation existing between the filament current and the electron emission from the filament in a special vacuum tube which has been designated as a regulator tube. At the lower limit of the operating speed range, namely, 4000 r. p. m., the filament of this regulator tube operates at a temperature which gives practically no emission of electrons. As the speed of the generator increases above this value the voltage rises, and accordingly the temperature of the regulator tube filament increases. This results in an extremely rapid increase in the

number of electrons emitted by the regulator tube filament, which in turn causes a rapid increase in the current flowing through the differential field and the plate circuit of the regulator tube, as shown by the characteristic curves of Fig. 2. This current tends to reduce the total magnetization of the generator, and, as a result, the voltage regulation is maintained within extremely close limits.

While this voltage regulating device operates in an extremely satisfactory manner, the excessive speed variation of the generator imposes certain other requirements on the generator design

FIG. 1b.



Wind-driven generator, fan and regulator tube.

which make it desirable to reduce this speed variation. The development of a constant speed air fan has progressed practically to the point where designs are available for an air fan which will give an almost exactly constant rotational speed with a range of air speeds of at least 4 to 1. The use of such an air fan on future wind-driven generators for airplanes is a practical certainty.

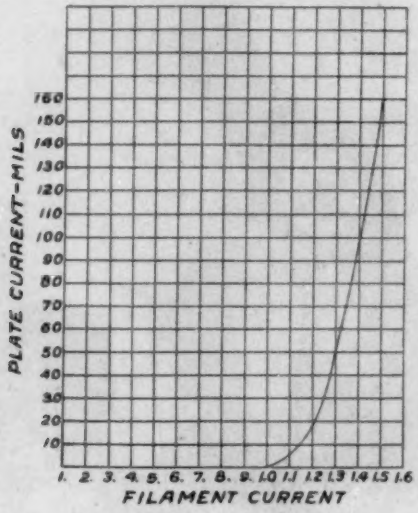
Various alternatives, such as storage batteries and a dynamotor, or a double voltage generator driven directly from the

airplane engine, were considered and rejected in favor of the generator above described.

TRANSMITTING SET.

The circuits of the transmitting set are shown schematically in Fig. 3. A single vacuum tube of a special type is used for furnishing the radio frequency current and a similar tube is used for modulating the radio frequency current. The method of modulation employed is known as the " constant current " method and may be described briefly as follows:

FIG. 2.



Characteristic curve, regulator tube.

The plate circuits of the vacuum tube oscillator and modulator are connected in parallel and are supplied through an inductance coil, which tends to maintain the total current constant. The plate current taken by the modulator tube is controlled by its grid voltage, which in turn is determined by the operation of the telephone transmitter. These voice frequency fluctuations of the modulator plate current cause corresponding variations in the direct current supplied to the plate circuit of the oscillator tube, the sum of the two currents at any par-

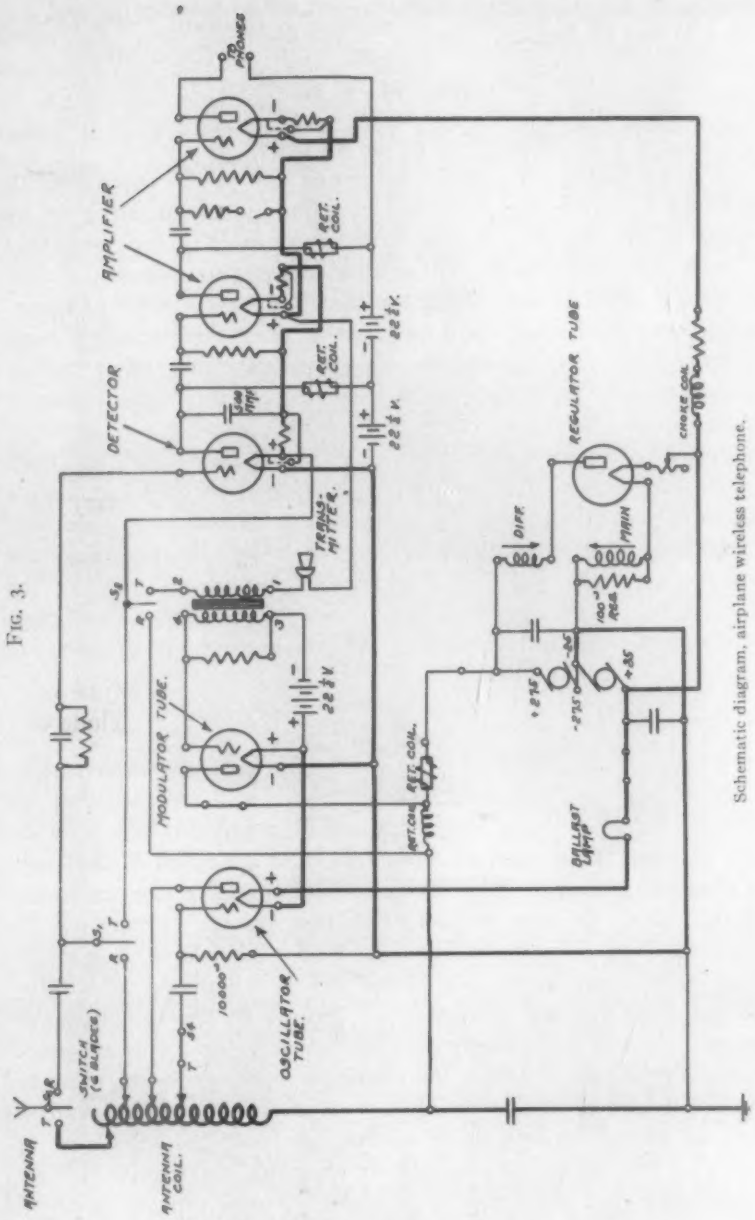


FIG. 3.

Schematic diagram, airplane wireless telephone.

ticular instance being substantially constant. These variations in the direct current supply of the oscillator tube result in corresponding variations of its high frequency output so that the result is a modulated radio frequency current supplied to the antenna.

The telephone transmitter furnished one of the most difficult problems in connection with the design of the transmitting set by reason of the fact that this transmitter operates under conditions of such extreme noise due to the wind and engine exhaust. After a very extended period of development the present form of transmitter was perfected, its improvement over the ordinary form being roughly indicated by the statement that the ratio of noise signals to speech signals in the output of this transmitter is probably less than 1 per cent. of the same ratio for a transmitter of the usual type.

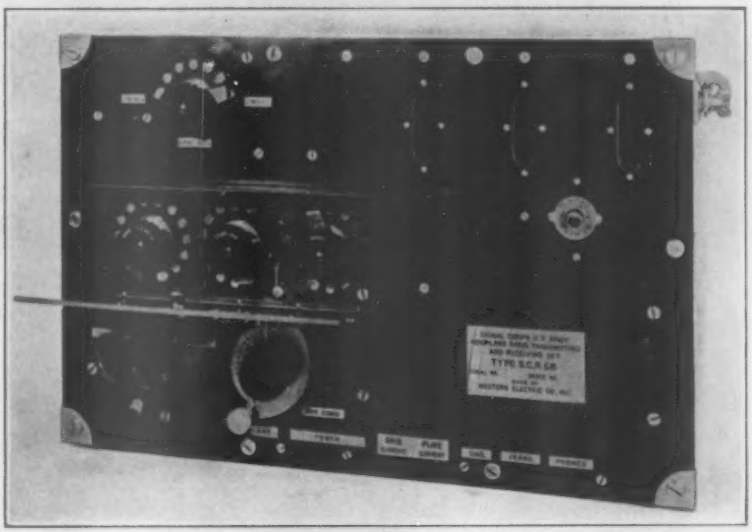
Reference to the schematic diagram indicates the adjustments of the transmitting set for different wave-lengths to include only a variable inductance and a variable capacity. Inasmuch as the apparatus is adjusted for a particular wave-length before the airplane leaves the ground, an artificial antenna whose constants approximate those of the normal antenna is used for making such adjustments on the ground.

RECEIVING SET.

The circuits of the receiving set are likewise shown schematically in Fig. 3. Reference to this figure will indicate that the circuit comprises a single resonant circuit, a vacuum tube detector, two vacuum tubes used as amplifiers, and a special helmet containing the receivers. The dectector and amplifier are not particularly novel in any respect, but the helmet containing the receivers is of very unusual construction. The same noise conditions which were mentioned above for the telephone transmitter likewise affected the reception of signals in the telephone receivers. It was accordingly necessary to develop a special sound-insulating helmet in which the telephone receivers were mounted in such a way as to exclude almost completely from the aviator's ears all sounds except those emanating from the telephone receivers. The design of a helmet which would accomplish this and at the same time not prove to be uncomfortable represents one of the most striking accomplishments in the complete set.

The adjustment of the receiving set is of the utmost simplicity, there being only a variable capacity and inductance to adjust for the particular wave-length of the received signal. As in the case of the transmitting set, these adjustments are ordinarily made before the plane leaves the ground, and it is usually necessary for the aviator to make in flight only an extremely small adjustment in the capacity to insure the proper tuning of the receiving set. Because of the condition of vibration existing on the airplane and the effect of this vibration on the vacuum tubes used in the

FIG. 4.



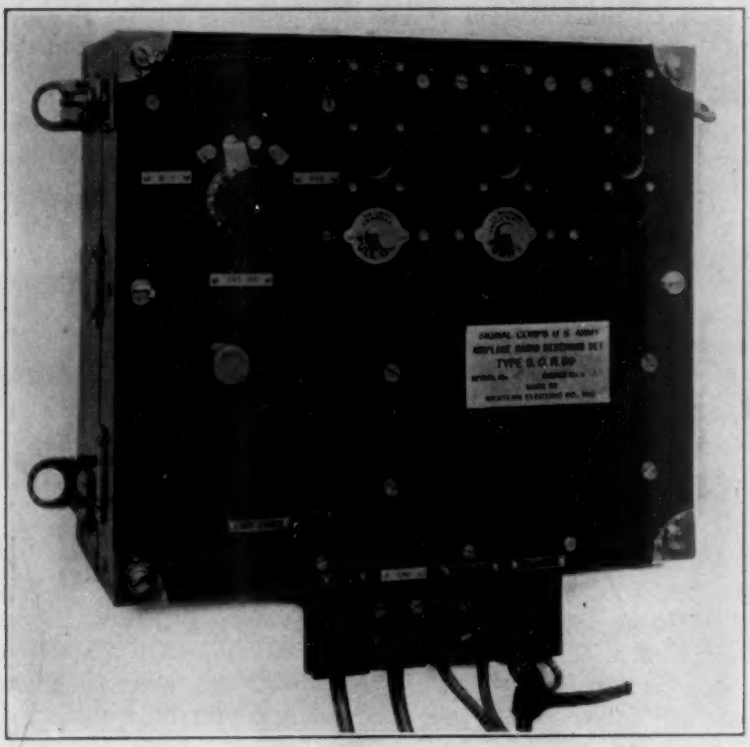
Transmitting and receiving unit.

receiving apparatus, it was necessary to devise a mechanical filter which would protect the vacuum tubes from these vibrations. The method finally adopted consisted of the use of sponge rubber supports for certain elements within the set box itself.

The current required by the plate circuits of the receiving tubes and the negative grid potential for the modulator tube of the transmitting set are furnished by small dry batteries, which consist of 15 cells of very special construction weighing less than one pound and having sufficient current capacity to operate the set a few hours a day for a considerable number of weeks. The most

important requirement for these batteries, however, was a sufficient length of shelf-life, inasmuch as a period of several months usually elapsed between the date of manufacture and the date of use. Difficulties of securing even a few months' shelf-life for cells of such small size made the use of standard cells out of the

FIG. 5.



Receiving unit.

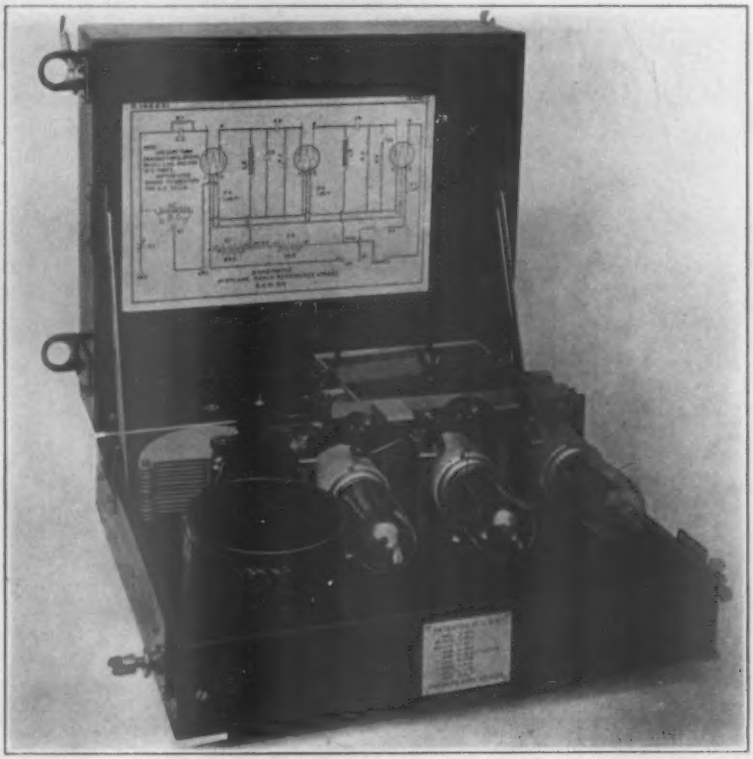
question. Development of particular types of containers for the cells and extremely careful selection of materials resulted in the satisfactory solution of this problem.

ANTENNA.

The form of antenna which was adopted for the early experiments with the airplane wireless telephone consisted of a wire

trailing behind the airplane in flight and connected through the apparatus with the frame of the airplane as a counterpoise. The length of this wire was ordinarily 300 feet. A reel was provided for holding this wire and a small weight was attached to the free end to cause it to unreel properly after the airplane left the ground. In order to reduce the attention required by the aviator

FIG. 6.



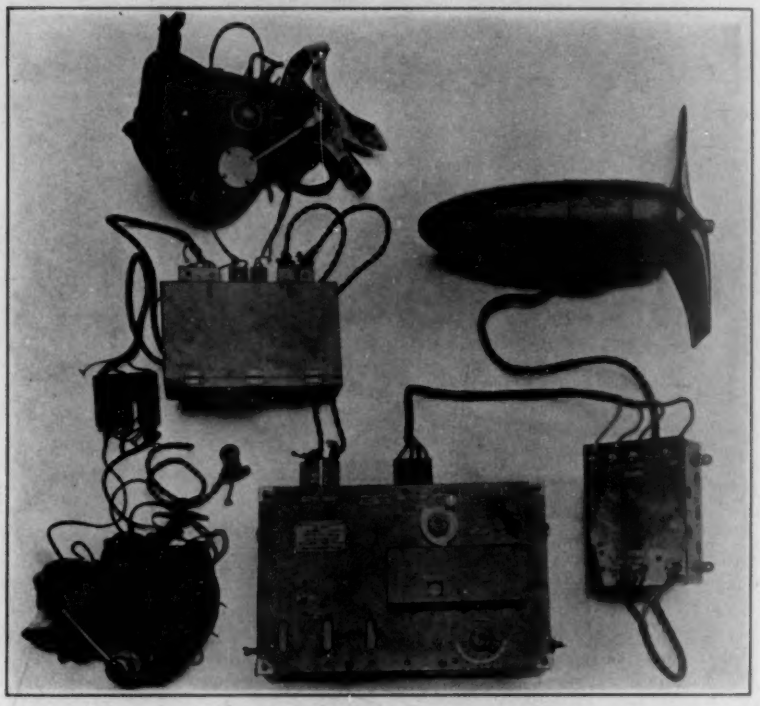
Receiving unit (open).

in unreeling the antenna a special form of reel was devised with a centrifugal governor, which limited the unreeling speed to a value which prevented the weight from breaking the wire at the end of the unreeling process. The wire which was used was a soft braided copper wire made purposely of low tensile strength, so that in case this wire became entangled with any obstruction

during flight no particular strain would be put upon the airplane structure before the antenna wire would break.

The subject of radiation from airplane antennæ has perhaps received less attention in proportion to its importance than almost any other phase of airplane wireless telephony. This is partly due to the fact that the form of antenna above described possesses

FIG. 7.



Complete transmitting and receiving set.

extremely efficient radiating properties and partly to the fact that investigations of the subject require very extensive and painstaking measurements involving actual flights of airplanes. The investigations conducted during the war, however, included a large number of tests of various types of antenna, the principal object of which was to evolve a substitute for the long trailing wire which would be better adapted for use on airplanes engaged

in acrobatic flying. Obviously the movements of an airplane were somewhat restricted by the use of this type of antenna.

Without indicating in detail any of the alternative types of antenna which were developed and used it may be stated there are a number of forms of airplane antenna which offer considerable promise of complying with the radiation requirement and at the same time offer practically no interference with the movements of the airplane.

The tactical uses of the airplane wireless telephone called for transmission and reception on certain airplanes and for reception only on other airplanes. The apparatus developed therefore included two distinct types, one including both the transmitting

FIG. 8.

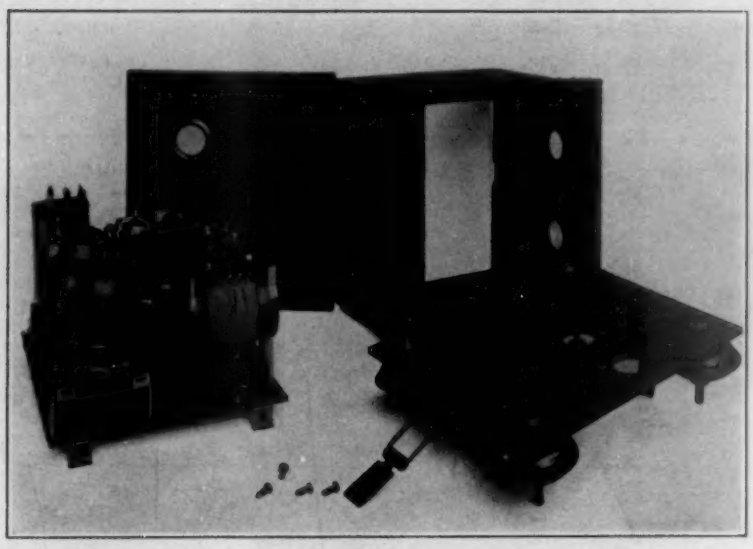
New type of airplane wireless telephone.

and receiving elements mounted in a single box, as shown in Fig. 4, while the other included only the receiving element as shown in Figs. 5 and 6. The complete equipment comprising the transmitting and receiving set is shown in Fig. 7. The complete equipment comprising the receiving set only is different with respect to the power plant, which in this case consists of a 4-volt storage battery. This figure shows two telephone transmitters and two helmets, which are used in connection with an interphone system provided as an auxiliary to the wireless telephone. This interphone system enables two persons in the same airplane to converse with each other by ordinary telephone, and furnishes in itself a valuable communication system entirely exterior to the wireless telephone apparatus.

Where communication between an airplane and a ground station is desired this communication is effected by means of a special ground set which has been developed to correspond with the range and wave-length requirements of the airplane apparatus.

In using the apparatus above described, the only manipulation required of the aviator is switching from the transmitting to the receiving apparatus, or *vice versa*, as required. Ranges of several miles between planes are easily accomplished, and under

FIG. 9.



Transmitting unit alone.

extremely favorable conditions much greater distances have been covered.

NEW TYPE OF APPARATUS.

Experience in the operation of the above type of wireless telephone apparatus indicated the desirability of certain improvements, particularly along the following lines:

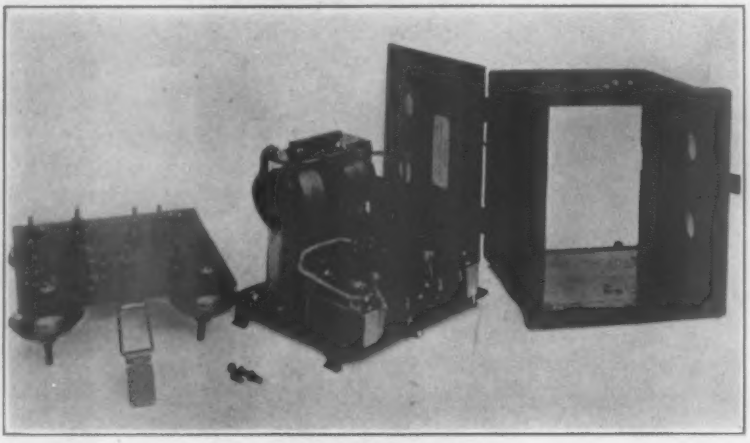
Reduction in the size of the apparatus units to better adapt them to installation in the restricted space available on certain types of airplanes.

Use of very much shorter wave-lengths to make

possible the substitution of antennæ which would not interfere with the use of the airplane and which would likewise reduce the amount of radio interference which would be experienced on the Western Front.

Accordingly, a new type of set was developed during the summer of 1918, the essential elements of which are illustrated in Figs. 8, 9, 10 and 11. Practical trials of this equipment have not proceeded sufficiently to indicate the superiority of this set from the standpoint of its use by the aviator. Its superiority, however, from the standpoint of installation is self-evident.

FIG. 10.



Receiving unit alone.

WIRELESS VS. WIRE TELEPHONY.

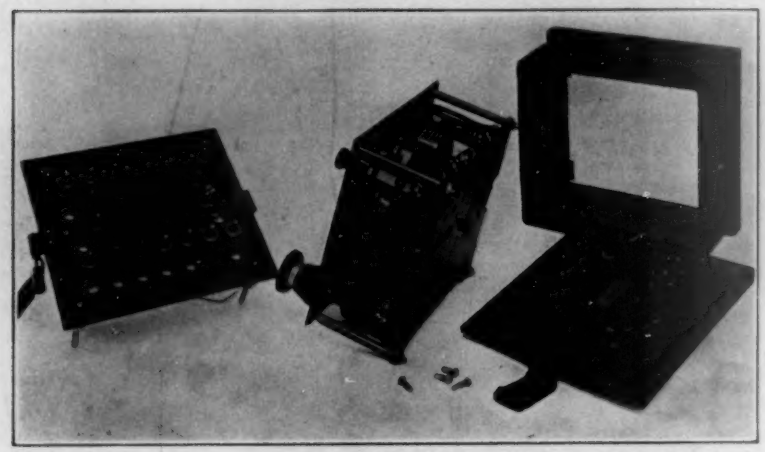
Any prophecy as to the future of the wireless telephone art should take due account of fundamental differences between wire and wireless telephony. While it is conceivable—though not probable—that improvements in directive radiation may be evolved which will cause the greater part of the waves radiated from a wireless station to choose a particular path, rather than to be spread broadcast as at present, there will always be a far more definite and restricted path for wire telephone signals than for wireless signals. As a result, it may be safely predicted that wireless telephony is not apt to supersede wire telephony in any of the fields now occupied by the latter. The application of wireless

telephony to new fields, where wire telephony is either impossible or impractical from economic considerations, will furnish abundant opportunity for service of the greatest value. A combination of wire and wireless telephony, each in its own field, may result ultimately in a telephone system covering the civilized world.

COMMERCIAL FIELD.

To the average person the most interesting commercial application of wireless telephony is transoceanic, such as is suggested by the long-distance experiments mentioned above. While the

FIG. 11.



Control unit alone.

scientific aspects of the question are such that the development of suitable apparatus for effecting reliable commercial service between such points as New York and London is a comparatively simple matter, economic questions have up to the present prevented serious consideration of such a project. It is entirely conceivable that improvements in the art may soon bring the cost of such a system well within the limits imposed by economic considerations.

Wireless telephony between ships at sea or between a ship and a shore station is a logical supplement to the wireless telegraph service now furnished on practically all ocean-going steamships. In this case, as in the case of transoceanic telephony, economic

considerations are apt to retard the extension of this field until the development of apparatus less expensive than present types.

In the field of aviation, however, wireless telephony presents a number of advantages which it is believed will result in its rapid adaptation to the needs of this service. Entirely aside from the popular interest attached to telephone communication between different airplanes, or between an airplane and a ground station, the practical value, particularly of the latter, is sufficient in many cases to justify the required expenditure to provide this facility.

There are various special fields not included in the above which may call for the use of wireless telephony, such as communication between various islands of a group—for example, the Hawaiian Islands—the wireless telephone furnishing in this case trunk lines for tying together the telephone exchanges on the various islands.

MILITARY FIELD.

The use of wireless telephone apparatus in combatant military operations during the war was practically negligible. This should, however, not be interpreted as an indication that wireless telephony offers no advantages for military purposes, but rather that the training of personnel in its use had not proceeded sufficiently to warrant its use. Communications within various units of an army frequently call for extreme mobility of the apparatus. The prevailing method of establishing intermittent communication between temporary stations joined by wires laid on the ground is obviously far from ideal. If wireless telephone apparatus can be developed by means of which different centres of command can be kept in constant touch with each other while all are in motion the advantages of such communication will compel its adoption and wide use throughout the communication system of the Army.

In naval operations the use of wireless telegraphy is so widespread that it forms an indispensable link in the naval communications system. For certain kinds of service the advantages offered by telephony as compared with telegraphy make it extremely desirable that wireless telephone apparatus be developed to meet the requirements. The present state of the art indicates the certainty that this can be done.

In the field of military aviation wireless telephony finds its greatest present opportunity for immediate service. The require-

ments of interairplane communication are such that the telephone is peculiarly adapted. The use of wireless telephony within an airplane squadron at once makes possible the development of the squadron into a military unit wherein the various members are subject to the command of the leader in exactly the same way as military units on land and water. The development of airplane squadron tactics is therefore made entirely possible, whereas without the telephone it is considered that the difficulties of communication between various airplanes would have made such a development impossible. Communication between airplanes and ground stations comprises an equally important phase of the operation of military aircraft. Hitherto these communications have been chiefly those for directing artillery fire and the wireless telegraph has served this purpose reasonably well. The availability of the wireless telephone, however, will open up new possibilities in the use of airplane to ground communication, an example of which is furnished by the present operations on the Mexican border. Scouting parties, accompanied by airplanes, traverse the extremely mountainous country, with airplanes preceding the land forces and at intervals reporting their observations. If we imagine each of the scouting parties to be equipped with receiving apparatus sufficiently portable so that it does not in any way interfere with the movements of the party, it is at once evident that they could, without delay, be kept informed of the observations of the aviator, by direct telephone communication. This extension of range of vision would be of immeasurable value.

Developments which have occurred during the war period, while essentially of a military character, are immediately applicable to both military and commercial needs. These developments point the way to further progress in the art which it is believed will, within a short time, establish wireless telephony as an important element in many phases of our military and commercial activities.

HYPERSENSITIZING COMMERCIAL PANCHROMATIC PLATES.*

BY

SAMUEL M. BURKA, Ph.D.

INTRODUCTION.

ORDINARY dry plates, which owe their sensitivity to the silver halides alone, are sensitive only to the violet and blue regions of the spectrum. If, however, a suitable dyestuff be added, the emulsion becomes sensitive to other regions, the particular region depending on the dye used. Thus erythrosin sensitizes to the green and greenish yellow, pinaverdol to the green and yellow, pinacyanol to the orange and red and dicyanin to the extreme red and infra-red.

The dyestuff is applied to the halides in one of two ways. In the commercial orthochromatic (sensitive to green and yellow) and panchromatic (sensitive to all colors) plates, the dyes are incorporated in the emulsion and the mixture flowed over the glass plate. The second method consists of bathing an ordinary blue-sensitive plate in a dilute solution of the dye and allowing the plate to dry.[1]

The bathed plates are in general faster than the commercial plates[2] and, of course, have the advantage that the plates can be sensitized for any desired region. Certain dyes, moreover (dicyanin, for example), cannot be successfully incorporated in the emulsion. The bathed plates, however, if not used soon after bathing, or if kept at a high temperature, are, in the case of most dyes, more susceptible to chemical fog. Dicyanin and pinacyanol bathed plates when prepared so as to produce the greatest sensitivity are useless after three or four days.

It has long been known that, though at the expense of keeping qualities and freedom from chemical fog, the speed of bathed plates can be increased by the addition of ammonia to the dye-

* Communicated by Dr. Enoch Karrer.

[1] Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169 *et. seq.* For the Bureau of Standards methods see Bulletin Bureau of Standards, 14, 371, 1917.

[2] Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169. Reference to Schumann, Oct., 1885; Phot. Wochenbl., 1885, p. 395.

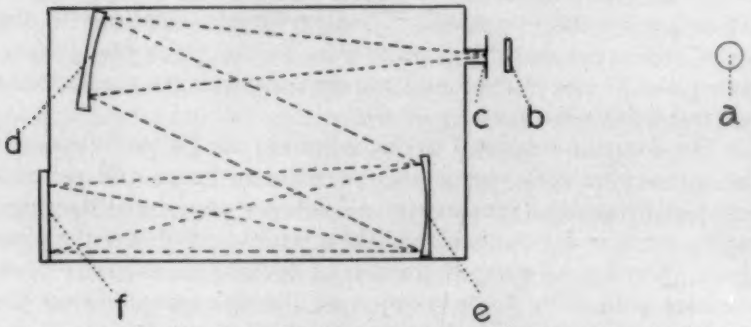
bath. Since this increase is quite marked in the case of some dyes, it was hoped that in this way commercial plates could have their speed increased, and, at the suggestion of Dr. P. W. Merrill, a study was made at the Bureau of Standards of the influence of ammonia on commercial orthochromatic and panchromatic plates.

SENSITOMETRY.

Three methods of sensitometry were used: first, the three-color screen method; second, the spectrograph method; and third, the Hurter and Driffield method.

The first method, based on Abney's method,[3] which, however,

FIG 1.



a, lamp source: *b*, yellow glass; *c*, slit; *d*, concave mirror; *e*, diffraction grating; *f*, plate to be tested.

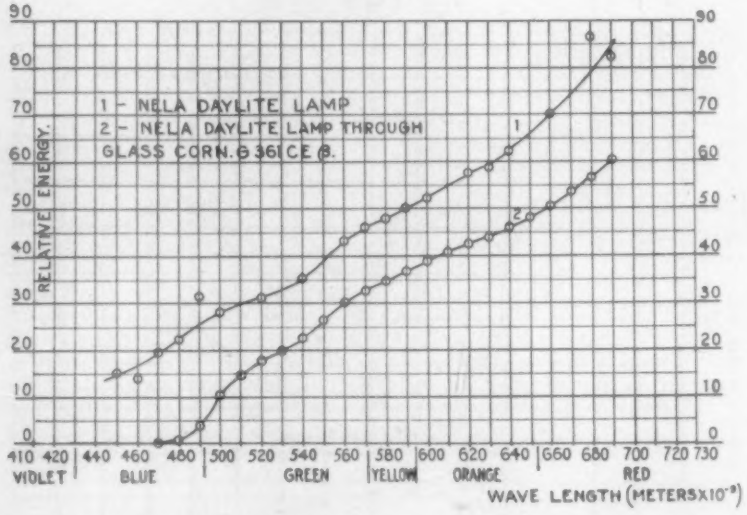
was used only as a qualitative method at first, consists of exposing the plates to a constant light source (usually a nitrogen-filled tungsten lamp corrected by color screens so as to have an energy distribution similar to daylight) behind a so-called trichromatic sensitometer plate. This plate is a neutral screen having four strips of squares of increasing density, each square having twice the density of the preceding. One of these strips is left white, while on the others are placed a red, a green, and a blue filter intended to be of the same luminosity and mutually exclusive. The plates to be tested are thus exposed to varying intensities of white, red, green and blue light.

The second method avoids the difficulty of obtaining filters transmitting pure spectral colors, by exposing the plate in a spectrograph.

[3] *Phot. Jour.*, June, 1895; Eder, "Phot. Korr.," 1903, p. 426. Chapman Jones, *Photo. Jour.*, 1901, 256.

The apparatus (Fig. 1) consists of a concave grating of 50 cm. radius with 20,000 lines per inch, mounted in parallel light with a 100-watt "daylight" tungsten lamp on 110-volt A. C. circuit as a source. For use with color sensitive plates a piece of yellow glass (7 mm. thick, Corning G 351 CE) barely transmitting the hydrogen blue line with wave-length 4861A was placed in front of the slit to cut out the second order blue. The region photographed was from about 4800A to the limit of sensitivity of the plate. A pair of cross-hairs just in front of the plate at

FIG 2.



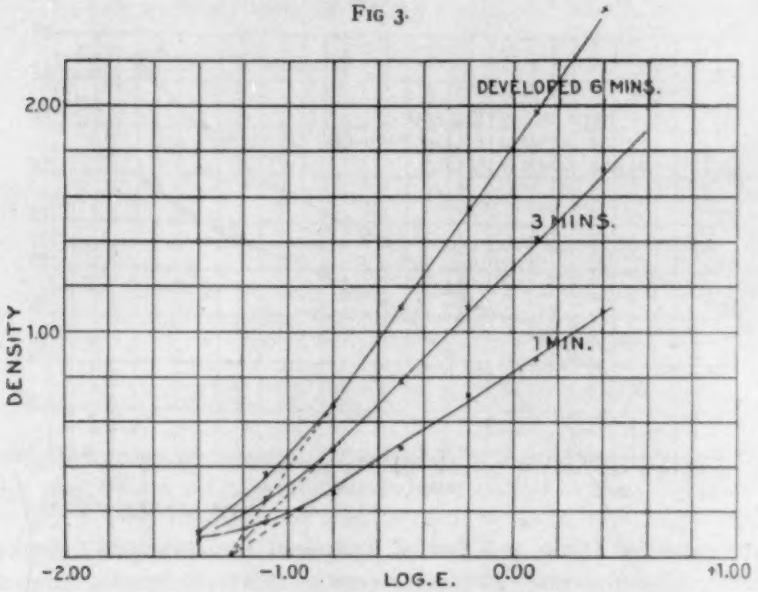
the position of the red line of hydrogen (wave-length 6563A) and of the blue line (4861A) served as reference marks. Fig. 2 gives the energy distribution of the lamp and screen combination. The energy was determined in the spectrophotometric laboratory, visually on a König-Martens Spectrophotometer, by a substitution method of comparison with a radiometrically calibrated Mazda lamp.

The photographic densities were measured on a Hartmann Microphotometer. This method gives immediately the sensitivity of the plate to all parts of the spectrum; but since, during the course of the work, minor changes (change of slit, resilvering of mirror, etc.) were made, the exposure times on different sets of plates were not always equivalent.

Furthermore, since the plates were of different kinds and showed markedly different rates of development, they were, in this part of the work, developed by tray until they showed the amount of fog allowable in plates to be used in general photography. The density of the silver deposit obtained depends on the time of development, so that in the curves obtained the shapes (maxima and minima) are the really important parts and the density is only approximately a measure of the speed.

The method generally adopted for the measurement of the

FIG 3.



Ilford special rapid panchromatic (5630N). Untreated; no filter; speed, 4.45.

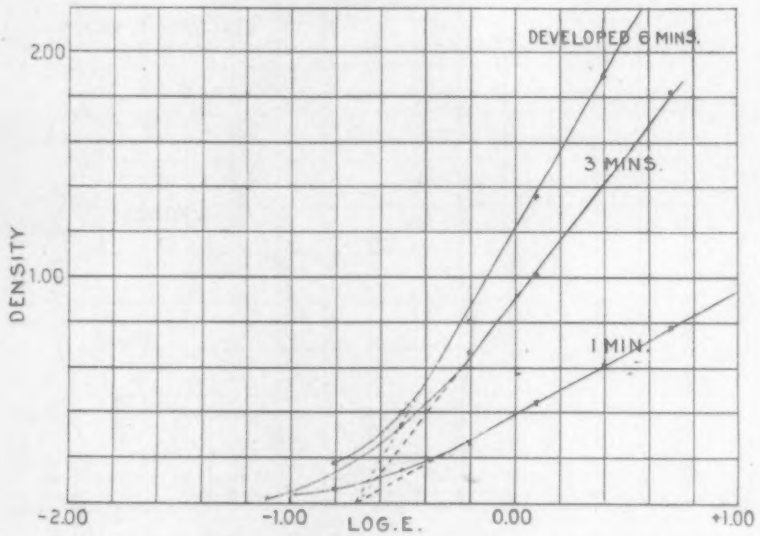
speed is that of Hurter and Driffield.[4] Specimens of the plate to be tested are exposed for the same time, behind a sectored wheel, to a standard light source. The transmissions, T, of the images obtained are measured and their densities, defined as $-\log T$, are plotted as ordinates and the logarithm of the time of exposure, E, as abscissas.

The curve so obtained is known as the characteristic curve of the plate. It consists of three parts: the first part is concave

[4] Hurter and Driffield, *Jour. Soc. Chem. Industry*, May, 1890, p. 455.

upward, the second is a straight line and the third is concave downward. Prolong the straight line part of the curve until it intersects the axis of abscissas. The numerical value of the exposure at the point of intersection is known as the inertia, *i*, of the plate and the speed is defined as $1/i$. Hurter and Driffield showed that this inertia of a plate is independent of the kind of developer used (except for strong pyro and for the presence of free bromide) and of the time of development (see Figs. 3 and 4). Free bromides, either in the film or in the developer, shift the point of

FIG 4.



Ilford special rapid panchromatic (563oN). Treated; no filter; speed, 18.2.

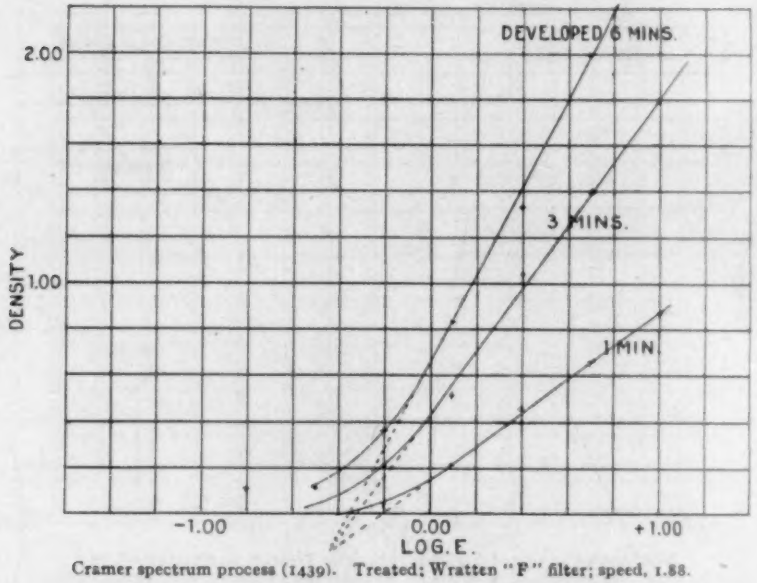
intersection of the straight line portions of the curves to a point below the axis. The plates for which Fig. 5 gives the characteristic curves contain free bromide in the emulsion.

The Hurter and Driffield speeds for several ammoniated and unammoniated plates were obtained, using an apparatus designed and built by Mr. R. Davis of the Bureau of Standards. The light source (a calibrated tungsten lamp) is corrected for daylight, and means are provided for accurately controlling the current through the lamp, the speed of the sectored disc and the total time of exposure.

PROCEDURE.

A series of Cramer Spectrum Process and Ilford Special Rapid Panchromatic plates were bathed for four mintes at 16° to 18° C. in water containing increasing amounts of ammonia, and were then exposed in the spectrograph. Both Metol-Hydroquinone and Pyro developers were used. It was soon found that the plates showed fog in development unless they were kept cool while drying and were dried rapidly. The plates showed a progressive increase in speed with increase in ammonia concentration

FIG 5.



Cramer spectrum process (1439). Treated; Wratten "F" filter; speed, 1.88.

until, with a bath containing 4 c.c. of ammonia water (containing 20 per cent. NH_3) in 100 c.c. distilled water, the plates began to fog so badly in development as to be useless.

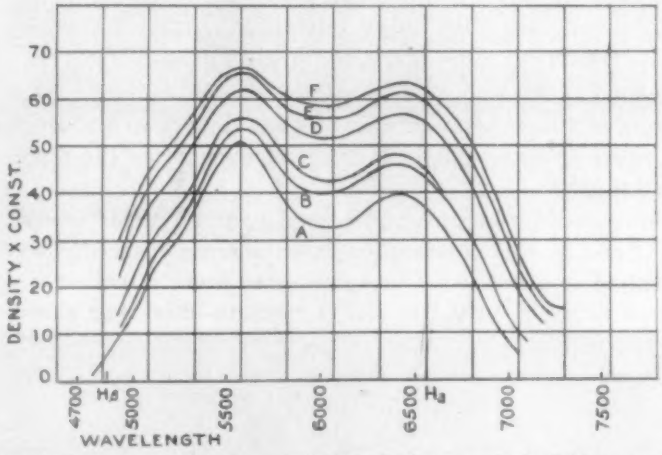
The ammonia was then added to water-alcohol mixtures of varying concentrations. The plates bathed in the alcoholic ammonia did not have their sensitivity increased as much as in the corresponding water baths, but were very much cleaner working. Seventy-five parts of water to twenty-five of ethyl-alcohol gave the best results, and this proportion was adhered to thereafter. Sometimes the plates showed a slight network of fog (mottling)

similar to the drying marks shown when plates are dipped (not soaked) in alcohol to hasten drying. Washing in 95 per cent. alcohol for 20 or 30 seconds after the ammonia bath prevented this, but this final wash is not usually necessary, especially if the plates are not forced in development.

Fig. 6 gives the spectral sensitivity curves of a series of Cramer Spectrum Process plates in baths containing $^1/_{40}$, $^1/_{10}$, $1/2$, 1 and 3 c.c. of 20 per cent. NH_3 ammonia water to an alcohol-water mixture of 25 parts of alcohol and 75 parts of water.

Three to $3\frac{1}{2}$ c.c. of the strong ammonia to 75 c.c. of water and

FIG 6.



Cramer spectrum process (1439). *A*, untreated; *B*, $^1/_{40}$ c.c. ammonia; *C*, $^1/_{10}$ c.c. ammonia; *D*, $^1/_2$ c.c. ammonia; *E*, 1 c.c. ammonia; *F*, 3 c.c. ammonia; 75 c.c. water; 25 c.c. alcohol. Same exposure and development.

25 c.c. alcohol was adopted as the combination to be used, and except for a few trials on various plates, the plates were all treated with this same mixture.

The time of bathing, 2, 4, or 6 minutes, had no appreciable effect, provided that the film was bathed long enough to get thoroughly soaked. Four minutes was the time used for bathing in all subsequent experiments.

For a study of the keeping qualities of the plates, a number of Cramer Spectrum Process and Ilford Panchromatic plates were treated and samples of the treated plates exposed and developed after being stored for various lengths of time. The Cramer plates showed deterioration after a week but were still usable.

The Ilford plates were useless after 3 or 4 days. The plates bathed without the use of alcohol deteriorated more rapidly.

The bath of 3 to 3½ c.c. of ammonia water (20 per cent. NH_3), 25 c.c. of alcohol and 75 c.c. of water is recommended. Three and one-half c.c. of ammonia water to 100 c.c. of water is used where the maximum increase of sensitivity is desired, but the plates are much more susceptible to fog in development and must be used within a few hours of drying. Development should be carried out, using the Wratten Safelight No. 3 and over-development carefully guarded against.

ORDINARY PLATES.

As is well known, the speed of the silver halide emulsion can be increased by treatment before it is flowed on the plate. This treatment, known as "ripening," is usually either to keep the emulsion at a high temperature for some time or to add ammonia. This ripening by ammonia is effective even after the plates are ready for use.[5]

On ripened plates such as the Seed 30 and Central Special, and on the Seed 23, there is no appreciable increase in speed when they are bathed in ammonia. In some cases there is rather a slight decrease in speed. On one plate known to have been ripened by the ammonia process before coating (Central Dry Plate Co.) which, however, was not fresh, this increase in speed on subsequent bathing in ammonia was quite apparent.

Microscopic examination of the treated and untreated plates showed no difference in the size of the grain.

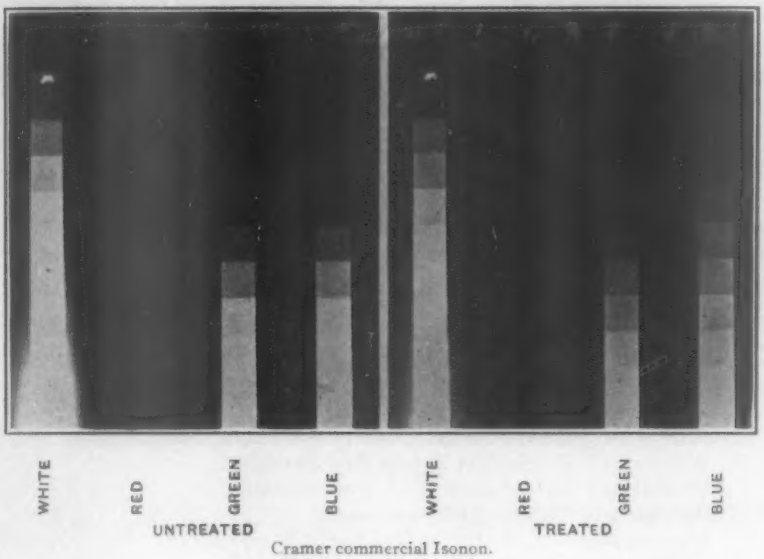
ORTHOCHROMATIC PLATES.

A number of plates sensitive to the green and yellow were tried. Most of them showed no appreciable change in sensitivity. Some had the sensitivity decreased, *e.g.*, Cramer Commercial Isonon. The sensitivity of the Seed Aero Ortho was increased slightly.

Fig. 7 is a print from treated and untreated Cramer Commercial Isonon negatives obtained through the tricolor sensitometer plate. Fig. 8 is a similar set on the Seed Aero Ortho. It will be noted that the change in sensitivity can be observed in all the strips.

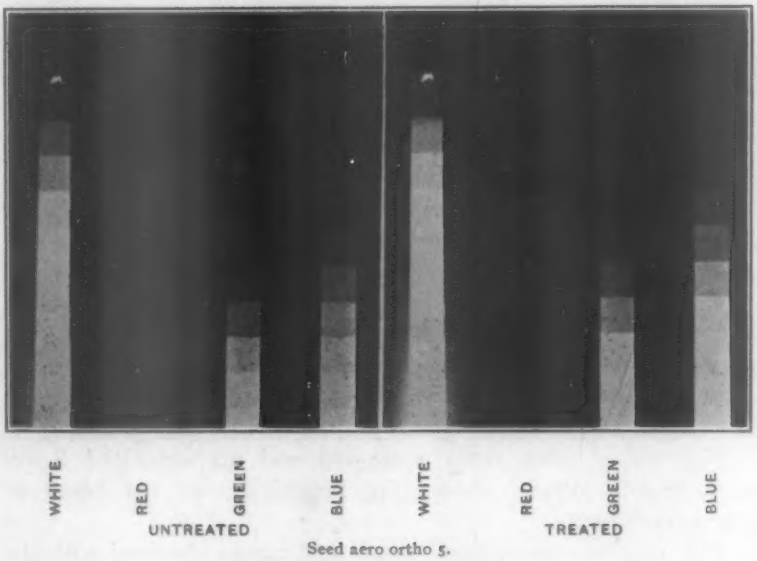
[5] Eder, "Handbuch," iii, p. 63.

FIG. 7.



Cramer commercial Isonon.

FIG 8.



Seed aero ortho 5.

The Cramer "Trichromatic" showed an increase in sensitivity comparable to that observed in the Spectrum Process.

Treatment of Eastman and of Ansco N. C. films, which are orthochromatic, showed no change larger than the differences attributable to experimental errors.

PANCHROMATIC PLATES.

Every panchromatic plate tried showed remarkable increase in speed. The very fast plates, several of which were developed only recently in response to the need for fast color sensitive plates for aerial photography, showed a somewhat smaller increase than the slower and process plates.

The plates examined were:

Cramer Spectrum Process;
Ilford Panchromatic (Special Rapid);
Five of the Eastman Special Experimental Panchromatic plates;
Wratten and Wainwright Special Red Sensitive;
Wratten and Wainwright R. F. C. Panchromatic;
Wratten and Wainwright Panchromatic;
Wratten M;
Cramer Spectrum No. 11;
Cramer G D I, G D II, G D III;
Central Experimental Panchromatic.

Wherever possible several different emulsions were used.

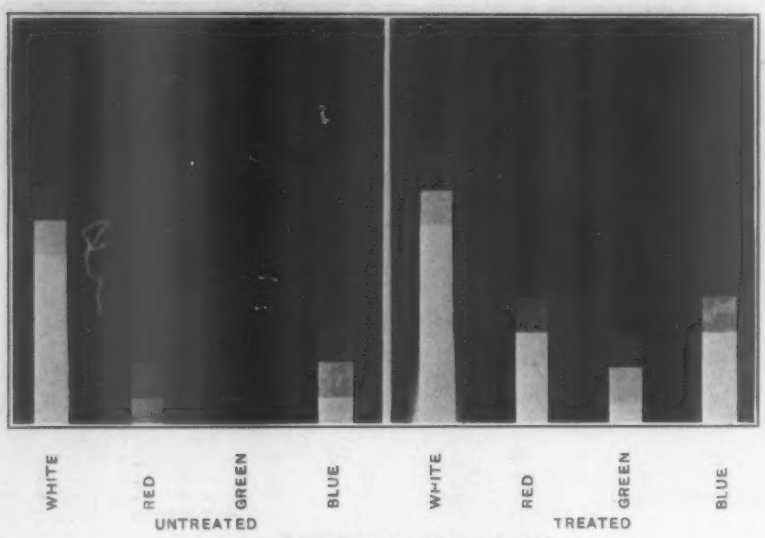
Figs. 9, 10, and 11 are prints from pairs of Wratten and Wainwright Special Red Sensitive, one of the Eastman Experimental emulsion and Ilford Panchromatic plates. The three sets of prints were exposed and developed exactly alike on Artura Iris paper. Even though the paper cannot reproduce all the gradations of the original negative, they do give fairly well the relative speeds of these three brands of plates and show quite well the great increase in speed effected by the ammonia treatment.

This sensitometer plate method gives the relative speeds of plates towards filters, but since the filters do not transmit pure spectral colors (the blue transmits a band in the red and the transmission of the three filters overlap) more can be learned of the color sensitivity from the spectrograph curves.

Fig. 12, a print from a treated and an untreated Spectrum Process Plate, shows the sensitivity of the plate to each wave-length.

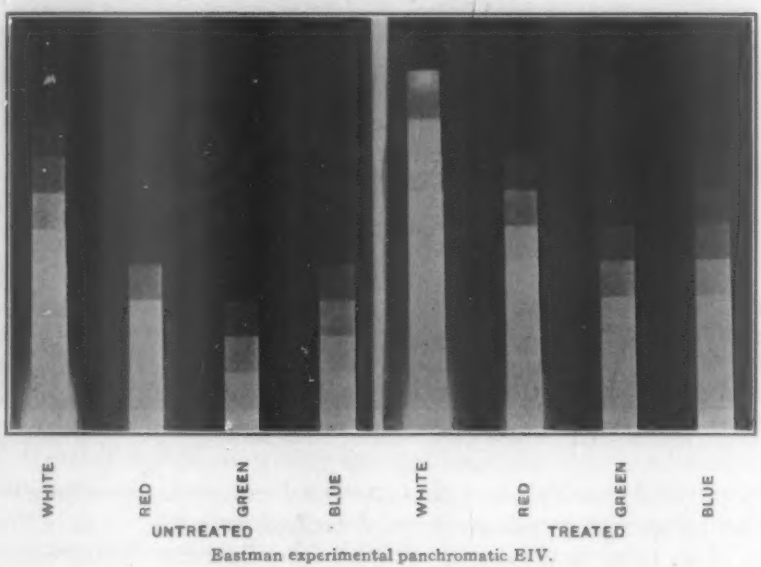
Fig. 13 gives the spectral sensitivity curves obtained with the

FIG 9.



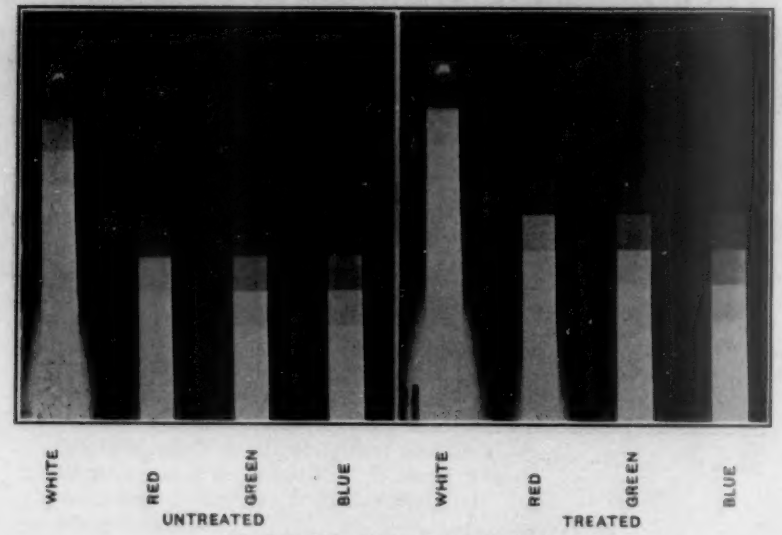
Wratten & Wainwright special red sensitive.

FIG 10.



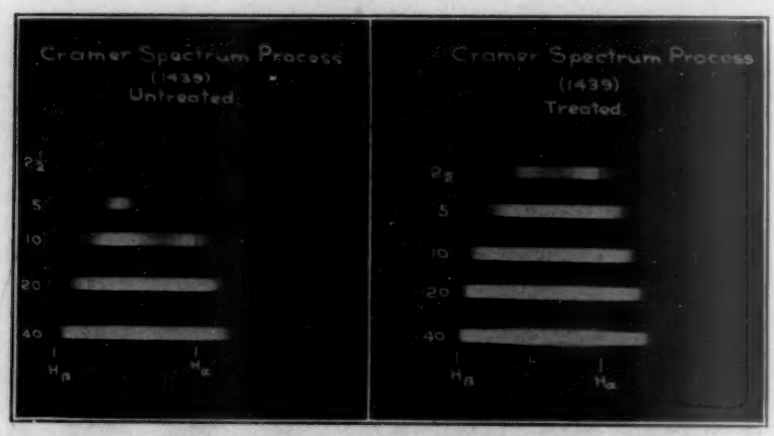
Eastman experimental panchromatic EIV.

FIG 11.



Ilford special rapid panchromatic 56418.

FIG 12.



Cramer spectrum process (panchromatic).

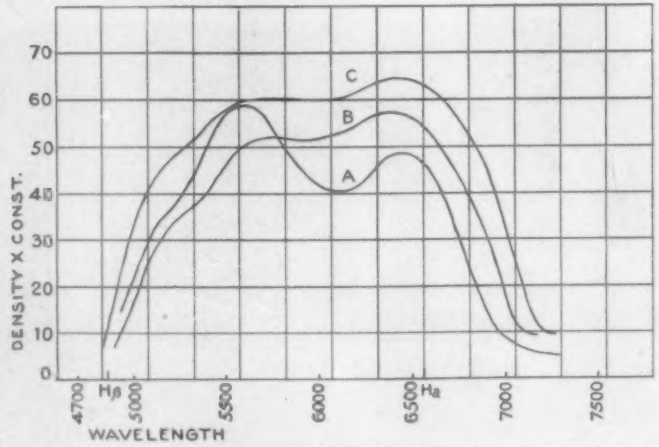
Spectrum Process plate: 5- and 10-second exposures on the treated and 10 seconds' exposure on the untreated plate.

Fig. 14 gives the curves for one of the Eastman Kodak Com-

pany's special experimental Panchromatic Plates. Both curves are for 10-second exposures.

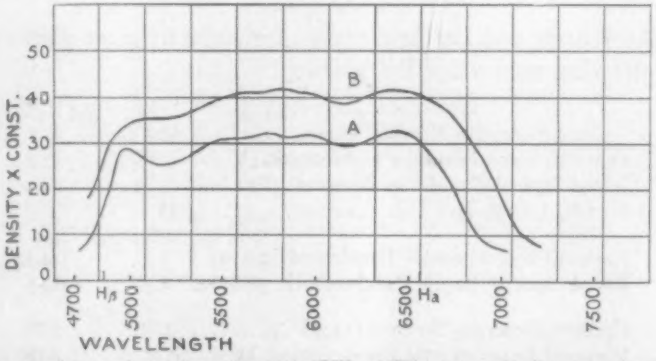
In Fig. 15, curve *A* is for the 10-second exposure on the un-

FIG 13.



Cramer spectrum process (1439). *A*, untreated, 10-second exposure; *B*, treated, 5-second exposure; *C*, treated, 10-second exposure.

FIG 14.



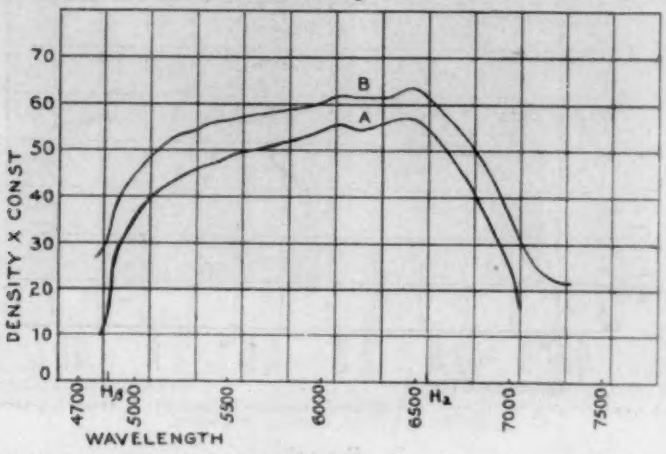
Eastman special experimental panchromatic (EIV 2165D). *A*, untreated; 10 seconds exposure *B*, treated, 10 seconds exposure.

treated Ilford Panchromatic plate. Curve *B* is for the 5-second exposure on the treated plate.

One of the most striking changes produced by the ammonia treatment was the action on old panchromatic plates. A Wratten and Wainwright plate marked "use before September 15, 1915," was exposed on October 21, 1918, in the spectrograph. As was

to be expected, the plate was badly fogged on the edges and the sensitivity of the emulsion was much below that of a fresh plate. Treatment with ammonia brought the sensitivity up to an even greater value than that possessed by a fresh plate (see Figs. 16 and 17).

FIG 15.



Ilford special rapid panchromatic (56418). *A*, untreated, 10 seconds exposure; *B*, treated, 5 seconds exposure.

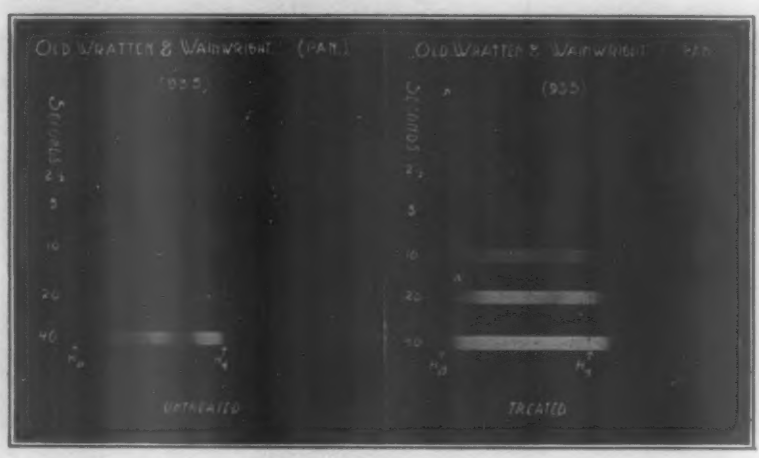
The Hurter and Driffield curves for some of these plates gave the following values for the speed:

	Untreated	Treated
	White Light	
Cramer Spectrum Process (1439)	10.2	25.1
Eastman Experimental Panchromatic IV d..	12.6	17.7
Ilford Special Rapid Panchromatic 5630 N..	4.45	18.2
Standard Orthonon	23	
	Minus Blue Filter	
Eastman Experimental Panchromatic 2199..	1.91	4.37
Ilford Special Rapid Panchromatic 56,416..	4.37	13.5
	F Filter	
Cramer Spectrum Process (1439)	0.49	1.88
Eastman Experimental Panchromatic IV d.	0.57	2.18

The figures give the absolute speeds of the plates to white light and through the Wratten Minus Blue and F Filters on the Hurter and Driffield scale. The value for the speed of the Standard Orthonon plate to white light obtained on the same apparatus is given for comparison. The Minus Blue, a deep yellow filter, cuts out all the blue and violet light, while the F, a deep red, transmits only the long red wave-lengths.

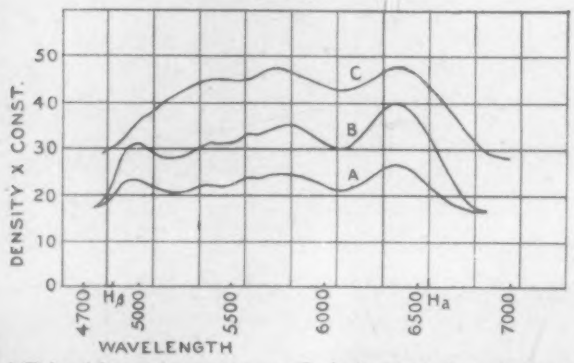
These figures show the remarkable increase in speed of the plates, particularly in the long wave-length region. Thus the Cramer Spectrum Process plates are increased in speed 150 per

FIG 16.



Wratten & Wainwright panchromatic. Expiration date, September 15, 1915. Used October 21, 1918.

FIG 17.



Wratten & Wainwright panchromatic (935). Expiration date, September, 1915. Used, October, 1918. *A*, untreated, 10 seconds exposure; *B*, untreated, 20 seconds exposure; *C*, treated, 10 seconds exposure.

cent. to white light and nearly 400 per cent. to the red. Through the Minus Blue filter one of the Ilford plates is increased 300 per cent.

These plates were used in experiments in airplane photog-

raphy, where for photographing through the haze a fast red-sensitive plate is necessary. Fig. 18 is a set of prints from the Ilford plates. Prints *a* and *b* were printed for the same time from the untreated and treated plates. Print *c* is from the untreated negative timed to give the best print. The negatives were given the same exposure in the air and were exposed within a few seconds of each other through the Minus Blue filter.

FIG. 18a.

AMMONIATED PLATE. PRINTED 21 SECONDS.

Hypersensitized Ilford plate. $\frac{1}{150}$ second exposure. Minus blue filter. Oblique from 4,000 feet.

The increased speed of the treated plate is apparent. It will be seen, also, that the treated plate is less contrasty and gives much better detail in the shadows.

Fig. 19*a* is from a Seed 30 plate used with no filter at an altitude of 17,000 feet on a slightly hazy day. Fig. 19*b* shows the same scene taken on a treated Spectrum Process plate through the A filter. The pictures were taken simultaneously in a multiple lens camera. The increased haze penetration obtainable by the use of the red filter is clearly shown.

FIG. 18b.

UNTREATED PLATE. PRINTED 21 SECONDS.

Ilford panchromatic plate. $\frac{1}{15}$ second exposure. Minus blue filter. Oblique from 4,000 feet.

FIG. 18c.

UNTREATED PLATE. PRINTED 8 SECONDS

Ilford panchromatic plate. $\frac{1}{15}$ second exposure. Minus blue filter. Oblique from 4,000 feet.

ACTION ON MINIMA.

On every plate which had an irregular curve of spectral sensitivity, the minima were raised and in many cases smoothed out entirely. For example, note the minima at 6100A (Fig. 13), at 5200A and 5850A (Fig. 14), and at 5200A and 6100A (Fig. 17). This property of the ammonia treatment adds greatly to the value

FIG. 19a.

SEED 30 PLATE. F/11. NO FILTER.
30° oblique from 17,000 feet. Hazy day. $\frac{1}{50}$ second exposure. Taken simultaneously with 19b in a multiple lens camera.

of the plates in the photography of spectra, especially as the sensitivity is extended some 200 Ångström units further into the red at the same time. The bad effect of a minimum is, however, smoothed out to some extent in ordinary photography through filters.

PLATES WITH KNOWN DYESTUFFS.

The difference in behavior between the ordinary and orthochromatic plates and the panchromatic plates shows clearly that

the sensitivity increase dealt with here is not that observed by Eder, which is due to "ripening," but is an action associated with the dyestuff.

The effect of the ammonia is to increase the sensitivity of the emulsion to the incident light and not to increase the developability of a latent image already formed, since a plate treated with

FIG. 19b.

HYPERSENSITIZED CRAMER SPECTRUM PROCESS PLATE. F 4.5. WRATTEN A FILTER.

30° oblique from 17,000 feet. Hazy day. $\frac{1}{100}$ second exposure. Taken simultaneously with 19a in a multiple lens camera.

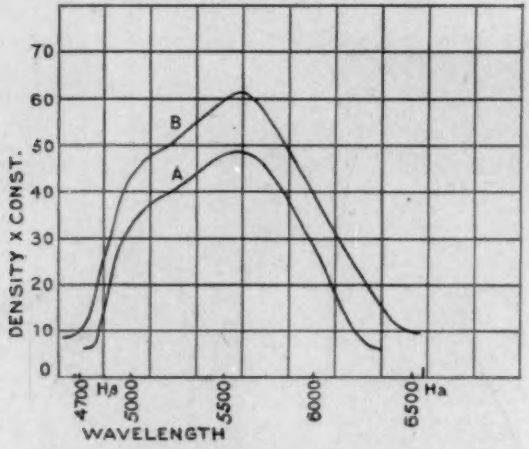
ammonia after exposure but before development showed no increase in sensitivity. That the action is not due to the alkalinity of the bath is shown by the fact that bathing in a solution of sodium hydroxide having the same concentration of OH ions had no effect on the speed of the plate.

Part of the increase in speed is, probably, due to the fact that some of the dyestuff in the gelatine film is washed out and

its screening effect diminished. The ammonia bath becomes colored with use and a color difference is observed between the untreated and treated plate before development.

The pinaverdol dyes sensitize for the green and yellow and an orthochromatic plate containing one of this series of dyes has the sensitivity increased by the ammonia treatment. Fig. 20 is a plate made up by the Cramer Dry Plate Co., using pinaverdol Pv. I., made by the Bureau of Chemistry, and marked by Cramer "similar to Trichromatic." The Trichromatic plate has the sensitivity curve of a pinaverdol dyed plate and Fig. 21 gives the curve before and after ammonia treatment.

FIG 20.



G D IV. PvI (similar to trichromatic); *A*, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

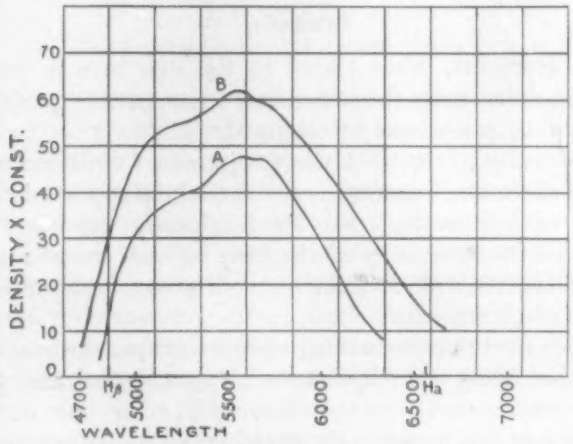
Mixtures of pinaverdol and pinacyanol are the dyes usually used in the preparation of panchromatic plates intended for spectrum photography. The mixture of these two dyes alone leaves a strong minimum at about 6100A. The ammonia treatment smooths out the minimum. In many plates intended for general photography other dyes are added to sensitize in this region (see Fig. 17).

Fig. 22 gives curves for a plate (similar to their Spectrum Plate) made up by the Cramer Co., using a mixture of the Bureau of Chemistry's pinacyanol, Pc. XII., and pinaverdol, Pv. I. It

will be noted that the addition of pinacyanol lowers the maximum due to the pinaverdol.

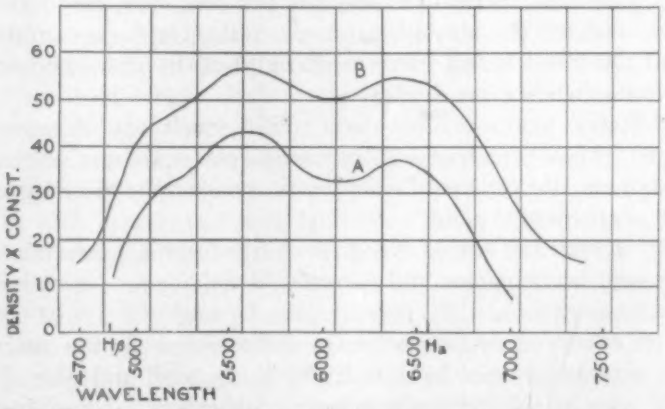
The dyes used in sensitizing are nearly all basic dyes, and it is not probable that the ammonia changes the dye itself. On the

FIG 21.



Cramer trichromatic, No. 21. *A*, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

FIG 22.



G D III. PcXII and PvI; *A*, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

addition of ammonia to the dye solution before bathing, there is no color change. It is possible that the solvent action of the ammonia on the silver halide facilitates the reaction between the

dyestuff and the silver salt, in addition to its softening effect on the gelatin. This, however, does not account for the raising of the minima. It is possible that there is the formation of a $AgNH_3Cl$ + Dyestuff molecule with a photosensitiveness slightly different from that of the original molecule.

SUMMARY.

Since ammonia, when added to the dye bath in preparing bathed plates, increases the sensitizing action of the dye, its action on commercial plates was investigated.

In the course of the work three methods of sensitometry were used. Of these, one was used as a first qualitative test; the second, the spectrograph method, was used to study the effect of the ammonia on the sensitivity of the plate to each wave-length; the third, the Hurter and Driffield method, gives the absolute value of the speed of the plate.

It was found that by bathing commercial panchromatic plates in a solution of 25 c.c. ethyl-alcohol, 75 c.c. water, and 3 c.c. of strong ammonia water (20 per cent. NH_3) for four minutes at 18° C. and drying rapidly, the speed to white light is increased 100 per cent. in nearly all cases, and the sensitivity in the red extended one hundred or more Ångström units. The speed in the red is increased, in many cases, 400 per cent. If the plates be bathed without the alcohol (100 c.c. water, 3½ c.c. ammonia water) the speed is still more increased, but the plates should be used immediately after drying.

Ordinary plates do not have their sensitivity appreciably changed. Most brands of orthochromatic plates are not improved, although one, the Cramer Trichromatic, showed the same increase as the panchromatic plate.

My thanks are due to Dr. J. S. Ames for his supervision of the present investigation and for valuable advice rendered during many conferences.

The energy distribution of the light source in the spectrograph was determined by Mr. E. P. T. Tyndall and Mr. H. J. McNicholas of the spectrophotometric laboratory. I am also indebted to Mr. R. Davis and Mr. F. M. Walters, Jr., through whose help the Hurter and Driffield curves were obtained, and to Dr. C. C. Kiess, under whose direction and coöperation most of the work was done.

WULFENITE: ITS CONCENTRATION AND SEPARATION FROM BARITE.*

BY

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DURING the past two years a number of articles concerning the mining and concentration of molybdenum ores have appeared in the technical and mining journals. These, however, have been confined almost wholly to the description of methods employed in the treatment of molybdenite (MoS_2) ore. This has been chiefly due to the fact that there are larger deposits of this mineral in the United States than of wulfenite ($PbMoO_4$), the other commercial molybdenum ore. The advent of flotation and its adaptability to the concentration of molybdenite resulted in the United States producing, during the war and since, more molybdenum than any country in the world. Several methods of concentrating molybdenite ores have been used with varying success, depending upon the grade and character of ore treated. The methods which have been successful on molybdenite include rolling and screening processes, surface tension and oil flotation processes and electrostatic methods. Oil flotation has proven so successful, especially on low-grade material, that it is being used almost exclusively. As a consequence, it would be safe to say that over 80 per cent. of the molybdenum produced came from molybdenite concentrates obtained by oil flotation, with an average extraction of 70–80 per cent. of the MoS_2 with a ratio of concentration of 100 to 1, depending upon the grade of product made. Colorado ranks first in the United States as a source of molybdenum, having produced during the year (1918) 665 tons of concentrates, figured on a basis of 90 per cent. molybdenum sulfide valued at $1,436,400.[1] This, when compared with the world production of between 250 and 300 tons (Mo) for 1915, indicates the importance of Colorado as a source of molybdenum from molybdenite ores. The principal working

* Communicated by the Director of the Bureau of Mines.

[1] Fifteenth Biennial Report of the Bureau of Mines, State of Colorado, 1917–1918, p. 107.

deposits in Colorado occur at Climax, Summit County, and near Empire, Clear Creek County. Other commercial deposits being worked at the present time occur at Questa, New Mexico; Pitkin, Colorado, and near Nogales, Arizona. Colorado, Arizona, New Mexico, California, Montana and Washington constitute the principal states where either molybdenite or wulfenite, or both, occur. These, as well as the minor deposits of molybdenum ores in the United States, are described by F. W. Horton.[2]

Little has been published concerning wulfenite ores and their concentration and, therefore, it is desired to emphasize in this paper the methods employed in the ore dressing of wulfenite ores—especially the separation of this mineral from barite gangue. Although there are several molybdenum minerals found in this country besides molybdenite and wulfenite, these two are the only ores of molybdenum that are considered of any commercial importance; the others being rare with one exception, molybdite ($Fe_2O_3.3MoO_3.7\frac{1}{2}H_2O$), which commonly occurs with molybdenite as an alteration product, and the recovery of which is difficult by the flotation process.

WULFENITE.

Horton[3] describes the mineral as follows:

> Wulfenite is a molybdate of lead ($PbMoO_4$) and theoretically contains 26.15 per cent. of molybdenum and 56.42 per cent. lead. It is a heavy, brittle, subtransparent to subtranslucent mineral with a resinous or adamantine lustre, and is generally of a wax or orange-yellow color. It may, however, be siskin and olive green, yellowish-gray, brown grayish-white to nearly colorless, or orange to bright red. Its hardness is 2.75 to 3 and its specific gravity is 6.7 to 7. It has a subconchoidal fracture and a white streak. In planes parallel with its crystal pyramid faces it has a smooth cleavage, but in other directions the cleavage is less distinct. It crystallizes in the tetragonal system with pyramidal hemihedrism. The crystals are commonly square and tabular and are sometimes extremely thin, with a vicinal pyramid replacing the basal plane. Less frequently the crystals are octahedral or prismatic, the prismatic faces showing the hemihedrism characteristic of the mineral.

QUALITATIVE TESTS.

1. One of the best tests is to fuse some of the pulverized ore with sodium or potassium carbonate to which a small amount of

[2] Horton, F. W., "Molybdenum, Its Ores and Their Concentration." Bulletin 111, Bureau of Mines (1916).

[3] *Loc. cit.*, p. 9.

potassium or sodium nitrate has been added. The fusion is treated with water, heated and filtered; the filtrate is acidified with HCl and boiled several minutes to expel all carbon dioxide. Some ammonium or potassium thiocyanate is added, followed by zinc; if molybdenum is present, a bright cherry-red color rapidly develops that will disappear only on prolonged standing in the presence of zinc. If hydrogen peroxide is added to the solution immediately after the cherry-red color has developed, the color disappears but returns as soon as the peroxide has been reduced. When only small amounts of molybdenum are present, if the solution is shaken with a small volume of ether after the thiocyanate and zinc have been added, any color in the liquid will be extracted by the ether and intensified as a golden-brown in the ether ring that forms at the top of the liquid on standing. This makes visible a color that before may have been imperceptible. Should the fusion be imperfect with an extraction of iron in the leach from the fused carbonates, a cherry-red color will immediately develop on the addition of the potassium or ammonium thiocyanate to the solution. On adding the zinc, however, the color due to iron disappears, and, unless a large quantity of iron has been brought into solution, this color will completely disappear prior to the development of any color due to molybdenum. If this color reaction of iron and its disappearance on addition of zinc are borne in mind, the above test for molybdenum is excellent.[4]

2. With the blowpipe on charcoal, wulfenite decrepitates and fuses, giving a yellow coating of lead oxide on the charcoal, and, when heated with soda ash on charcoal, it yields metallic lead; with a salt of phosphorus, it gives a yellowish-green glass in the oxidizing flame, which becomes dark green in the reducing flame; with borax in the oxidizing flame, it gives a colorless glass which in the reducing flame becomes opaque black, or dirty green.

3. A pinch of powdered molybdenum ore on a porcelain lid, if moistened with a few drops of nitric acid so as to make a paste, and heated nearly to dryness, then followed by 0.5 c.c. of concentrated sulphuric acid, will, after being heated to fumes and allowed to stand, produce a blue color when breathed upon; a drop of alcohol added at this point will hasten this color reaction. The color will disappear on heating, but if allowed to stand for

[4] Horton, *loc. cit.*, p. 40.

some time will reappear on cooling. Water will also destroy the color.

4. An alkaline solution of a molybdate free from iron, after acidifying with acetic acid, will, on the addition of potassium ferrocyanide or tannic acid, produce a deep red to brown coloration. Pyrogallol, under similar conditions, will give an orange coloration. None of the tests, however, are as sensitive as the ammonium or potassium thiocyanate test previously given.

OUTLINE OF METHODS FOR DETERMINING MOLYBDENUM IN WULFENITE ORES.

Wulfenite, when powdered sufficiently fine, is completely soluble in a mixture of hydrochloric and sulphuric acids, or nitric and sulphuric when taken to fumes. If desired, a mixture of the three acids may be used; only rarely will the residue from such acid treatments contain any undissolved molybdenum. After cooling the hot sulphuric acid, water is added; and then, without filtering off the insoluble matter, an excess of ammonium hydroxide. Boil, filter and wash well with hot water. Redissolve the precipitate in dilute sulphuric acid and reprecipitate, boil, filter and wash. The filtrate will be clear and colorless, and the molybdenum will be found in solution as ammonium molybdate. The filtrate is then acidified with HCl, and ammonium acetate added, followed by a few cubic centimetres of acetic acid. Lead acetate will precipitate from such solution lead molybdate as a white precipitate. Chromium, vanadium, tungsten and phosphorus will, however, interfere with this latter precipitation, and if their presence is known, they must be removed before the precipitation of molybdenum is made. Phosphorus is usually precipitated along with the iron group; however, to insure this precipitation it is advisable to add a few cubic centimetres of ferric chloride solution before adding the ammonium hydroxide. Chromium and tungsten are rarely found associated with molybdenum ores. Molybdenum is separated from vanadium by passing H_2S into a slightly acid solution under pressure.

The above acid method of decomposition forms the basis for the successful quantitative determination of molybdenum. At the point where the lead acetate is added to the acetic acid solution, a standard lead acetate solution can be run from a burette until a test drop gives no color change with a drop of tannic acid

indicator solution. This method is the reverse of the ammonium molybdate method for the determination of lead. Better results are obtained, however, if the lead molybdate precipitate is weighed. If desired, the molybdenum can be determined, after making the ammoniacal filtrate acid with surphuric, by passing through a Jones reductor and titrating with a standard permanganate solution. The details for the successful determination of molybdenum in ores, as outlined above, and the removal or determination of the interfering elements, have been definitely established and carefully worked out. This will be described in a Bureau of Mines technical paper.[5]

SOURCE AND IMPORTANCE OF WULFENITE.

Up to 1915, wulfenite ores constituted the principal source of molybdenum in this country. Horton [6] states that:

> Wulfenite ores from Arizona have supplied the larger part of the molybdenum produced in this country to 1915, and on account of the ease with which they are concentrated they should prove a strong competitor of molybdenite for markets that do not require concentrates with a high molybdenum content.

The deposits in Arizona are largely confined to the four southern counties, Cochise, Pima, Pinal and Yuma, with a few in Gila, Maricopa and Yavapai Counties. Besides the deposits occurring in Arizona, wulfenite has been reported in several scattered localities throughout the Western States of Nevada, New Mexico, Utah, California and Montana. The location, geology, extent and development of all these wulfenite deposits are given by Horton.[7] Several of these deposits of wulfenite might be worked at a profit and would have a better chance to compete with the molybdenite market if more were known regarding the metallurgical treatment of the concentrates. The writer has suggested in another paper—"Notes on the Metallurgy of Wulfenite," published in *Chemical and Metallurgical Engineering*, vol. xxi, Sept. 15, 1919, p. 364—a process for such treatment.

In general, it may be stated that deposits of wulfenite are confined almost wholly to veins in which it occurs with other lead minerals, but sometimes occurring in seams, stringers and cracks throughout ore bodies that are mined for gold and silver.

[5] Bonardi, J. P., and Barrett, E. P., Tech. Paper 231, Bureau of Mines, "Determination of Molybdenum."

[6] *Loc. cit.*, p. 45.

[7] Horton, *loc. cit.*, pp. 45–53.

CONCENTRATION AND ASSOCIATED MINERALS.

The successful concentration of wulfenite presents few difficulties, as the ordinary wet processes of concentration by jigs, tables and vanners, such as are used in concentrating mills for treating lead, copper, zinc and pyrite ores, may be applied with success on wulfenite ores. These ores are also amenable to pneumatic separators of various types, which can be used when it is difficult to obtain a water supply for the wet processes. Wulfenite rarely occurs in finely disseminated form, as is common with certain tungsten ores. A small amount of crushing will give a free cleavage of the mineral from the associated gangue; therefore, the conditions for wet concentration, or pneumatic methods, are favorable. In addition, wulfenite does not slime to the same extent as some of the more common minerals, such as galena and pyrite. The specific gravity is high, 6.7 to 7, so that it can readily be separated from the accompanying gangue matter, excepting the heavy minerals and barite.

Vanadinite and several of the lead minerals—cerrusite, anglesite, galena, pyromorphite and mimetite—which often occur with wulfenite, are also recovered in the wulfenite concentrates, as they have nearly the same specific gravity. Usually a concentrate of 15 to 20 per cent. MoO_3 is the best obtainable when the above mentioned lead minerals occur to any extent in the ore. Pure wulfenite contains 39.23 per cent. MoO_3 and 60.77 per cent. PbO. Wulfenite buyers sometimes specify that the concentrate should contain a minimum of 20 per cent. MoO_3, or 13.33 per cent. Mo. Though the presence of other lead minerals lowers the grade of concentrate, any metallurgical process recovering the molybdenum in the slag should also recover the lead as bullion, along with any accompanying gold or silver. The ores of the Mammoth mine, about 3 miles from Mammoth at Shultz, Pinal County, Arizona, were worked originally for their free gold content alone, which was said to be $6 to $7 per ton. Part of the tailings from these workings later supplied 750 tons of wulfenite concentrates out of 795 tons of combined wulfenite and molybdenite concentrates that constituted the total production of this county in 1903.[8]

[8] Pratt, J. H., "The Steel-Hardening Metals." Mineral Resources, U. S., for 1903, U. S. Geol. Survey, 1904, p. 308.

A flow sheet and description of the wet process employed in a wulfenite concentrating mill at Mammoth, Pinal County, Arizona, which treated the ore from the Mammoth mine at Shultz, is given by Horton.[9] This mill treated dump tails in which the ore had been originally crushed in a stamp mill and passed over amalgamation plates; later the tailing from this process was cyanided to recover the free gold lost in the first operation. After these two treatments were given the ore, although it was so fine that over 75 per cent. passed a 200-mesh, it was treated for wulfenite, which amounted to about 1 per cent., or equivalent to about .4 per cent. MoO_3. It was these tailings that supplied in 1903 750 tons of wulfenite concentrates out of the 795 tons of combined wulfenite and molybdenite concentrates previously mentioned. In 1915 it was estimated that these Mammoth tailings contained 200,000 to 250,000 tons of material of 1 to 2 per cent. wulfenite. Despite the low grade and the fineness, a recovery of about 70 per cent. was made in a concentrate averaging about 23 per cent. MoO_3 and 61 per cent. PbO. This was obtained after screening through 4-mesh, followed by simple classification by five "hindered settling" classifiers and one settling cone placed in series. The spigot product from these classifiers was sent to sand tables of the Overstrom, Ludwig, Card and Wilfley types. It was recommended to the company treating this material at that time (June, 1915) that the extraction of wulfenite could be considerably improved by the treatment of the fines on slime tables or slime vanners. The mill has been closed down for some time, since most of the molybdenum during the war was supplied from the sulphide ore (MoS_2). Whatever new changes had been made in the flow sheet up to the time of closing down, could not be ascertained, as the operators after closing the mill had moved out of the territory.

In order to show the wide range of processes that may be successfully applied to wulfenite ores in general, concentration experiments were carried out at this station by Horton [10] which resulted in high extractions. Horton concludes that wulfenite ores in general could be treated efficiently by wet concentration, approximately as follows:

[9] *Loc. cit.*, Bull. 111, Bureau of Mines, p. 177; *Min. and Sci. Press*, vol. cxiv, 1917, No. 8.

[10] *Loc. cit.*, p. 110–120.

After the ore has been crushed in a jaw or gyratory crusher to about one-half inch size, it should be further crushed in rolls to about one-quarter inch, and the product screened into three series of sizes. Approximately these sizes should be as follows: Through a 4-mesh and on 8-mesh, and through 8-mesh and on 12-mesh; these two sizes to be treated on jigs: through 12-mesh and on 20-mesh, through 20-mesh and on 40-mesh, through 40-mesh and on 80-mesh, and through 80-mesh and on 120-mesh; these four sizes to be treated on concentrating tables, and the material through 120-mesh to be treated on slime tables. The jigs should be operated so as to obtain as clean concentrates and tailings as possible, and the middlings, after recrushing (perhaps through 20-mesh), should be appropriately sized for reconcentration by the tables.

The above statement indicates the amenability of the ordinary type of wulfenite ores to ore dressing methods. Horton states, "the costs of concentrating wulfenite ores by wet processes are, in general, comparable to those of treating ores of galena, sphalerite, chalcopyrite, etc., by similar methods."

SEPARATION OF WULFENITE FROM BARITE.

Wulfenite has been found occurring with barite, and it is only when associated with gangue of such high specific gravity that the problem of separation and satisfactory recovery of the wulfenite becomes difficult, and the methods adopted for ore dressing should be carefully worked out. This problem will be taken up in detail in this paper. Since barite is the highest specific gravity gangue mineral that is found associated with wulfenite, it was deemed advisable to find out whether any special treatment would be necessary in its concentration. The ore from the Mammoth dump, cited above, did not contain any barite, so its separation from wulfenite did not enter into consideration. Horton cites no case where barite gangue was found occurring with wulfenite in any appreciable quantity.

A sample of wulfenite concentrate, whose principal gangue mineral consisted of barite, was kindly furnished to the Rocky Mountain Station by a copper company operating in Arizona. The company is developing a wulfenite mine containing considerable barite gangue matter associated with rhyolite, quartz, several lead minerals, such as mimetite, pyromorphite, vanadinite, cerrusite and anglesite, and a small amount of copper, principally in the

[11] The separation of vanadinite from wulfenite has long been considered a difficult problem; it is the writer's intention to carry on in the future an investigation of this problem.

form of chrysocolla. The milled ore assayed approximately 2 per cent. molybdenum; the mined ore is of a lower grade and must be sorted before sending to the mill.

BARITE "MIDDLING" MATERIAL.

The disposal or treatment of the middling material that was formed at the concentrating mill was held up pending the results of future ore dressing experiments. This middling material contained 52.20 per cent. barite ($BaSO_4$) and 5.50 per cent. molybdenum in the form of wulfenite. This product represented the barite concentrates or middling material taken from a Wilfley table in treating the original ore. In working on the original ore at the mill, it was found that passing the material once over a Wilfley table made a fairly clean concentrate and approximately a 60 per cent. extraction, if a great amount of this middling material containing the barite was rejected. This result was obtained on treating mined ore that had received no special treatment as to classification except grinding and a simple screening through approximately 10-mesh. Such a feed, when passed over a Frue vanner, gave a 63 per cent. extraction and a concentrate ranging from 15 to 17 per cent. molybdenum. In this connection, it can be stated that the adaptability of vanners to the treatment of wulfenite ores has been only recently noticed to any extent. In treating this particular ore, the vanner proved an excellent machine to remove the copper mineral from the wulfenite. Although it was known that wulfenite is somewhat friable, it was found that the very fine wulfenite minerals of an unclassified feed would, when submitted to a vanner, readily attach themselves to the moving surface and be retained. This is because the mineral is readily wetted; while the gangue particles, being of lower specific gravity and not so easily wetted, would be carried off by the stream of water, even though the larger in size. After obtaining the richer concentrates from the vanner and the Wilfley table, there still remained a middling product composed of grains containing both heavy and light minerals. It is this class of material which will be considered in this paper. It is composed chiefly of barite, quartz, wulfenite and several of the lead minerals already described. The wulfenite was present in particles ranging in size from minute specks to pieces retained by a 12-mesh screen.

PROCEDURE OF TESTS.

In testing an ore for ore-dressing possibilities, there is probably nothing so enlightening as screen classification, assay of products and experimentation upon them by different metallurgical processes. The use of the microscope in this connection also can not be over-emphasized.[12]

Accordingly, the so-called middling material, as received, was first screened into six products as follows:

Screen Analysis (Feed Assayed 5.50 Per cent. Mo.).

	Per cent. Wt.	Per cent. Mo.	Content Mo.
−10 +20	13.74	2.50	.344
−20 +28	14.40	3.00	.432
−28 +35	15.65	3.20	.473
−35 +48	17.35	9.67	1.678
−48 +65	22.50	7.40	1.665
−65	16.36	5.42	.887
	100.00	5.50	5.48 grams.

These screened products were examined separately under the microscope to ascertain the degree of locked wulfenite grains in order to determine whether the material would be classed as a true middling and would need any further crushing to liberate the wulfenite before submitting to further concentration. The treatment of middlings has followed, as a rule, two well-beaten paths: reground and returned to ore stream; or returned to ore stream without regrinding. This results often in mixing two products of widely different grades; the ore itself being perhaps of low content and the middlings of relatively high content, as regards the mineral to be saved. This fact must be borne in mind in studying the treatment to be given the material under discussion. On examination under the microscope, the plus 20-mesh was found to be the only screen product containing any locked material, and this was only small in amount. That the material as received was not a true middling was readily seen, as the term "middling" is applied to a crushed product, the individual grains

[12] The use of the microscope for use in connection with an ore dressing problem is described in another paper, "Approximate Quantitative Microscopy of Pulverized Ores," by W. H. Coghill and J. P. Bonardi, Tech. Paper 211, Bureau of Mines.

of which are composite; that is, they contain, attached to or imbedded in the gangue, particles of valuable mineral. Theoretically, no free grains of valuable minerals should be present, but in practice there will always be a varying proportion of such grains. The proportion of locked grains in this so-called middling material, being of such small proportion to the free grains, would readily classify it as not a true middling.

Next, in order to try out the separation of the wulfenite from the barite in the various screen products, as shown by the screen analyses, as well as on the unclassified material as received, the different sized products and unclassified material were submitted separately to a laboratory experimental size Wilfley table. Since the screen products were dry-sized between small limits, the separation of the free mineral grains of wulfenite from the gangue barite, in which the difference of specific gravity exceeds two units, should be an easy matter. The results of a few simple tests made on the small experimental size Wilfley table are as follows. The material in each run was passed but *once* over the table, and only the concentrates of each were collected, weighed and assayed.

TABLE I.

Concentration Tests on Small Experimental Size Wilfley Table.

Run	Mesh	Wt. taken	Per cent. Mo.	Wt. of Conc.	Per cent. Mo. in Con.	Per cent. Recovery Mo.	Remarks
1	Unclassified material	500 g.	5.50	28 g.	14.17	14.45	
2	−10 +20*	500 g.	2.50	none	....	....	No separation
3	−20 +28*	500 g.	3.00	none	....	....	No separation
4	−28 +35*	500 g.	3.20	50 g.	9.40	28.80	Poor separation
5	−35 +48	450 g.	9.67	205 g.	12.12	57.05	
6	−48 +65	450 g.	7.40	155 g.	13.16	61.20	
7	−65	500 g.	5.42	160 g.	12.60	74.50	

* The wulfenite crystals of these meshes, being large, thin tabular and flaky, rolled along over the table with the barite gangue, and no line of demarcation could be made between the minerals of different specific gravity.

Jigging of these sizes was not attempted, since the company submitting the wulfenite ore had not installed any jigs in the mill. Further, expert attention would, in all probability, be required in the successful operation of jigs treating material of such fineness; besides taking into consideration wulfenite which when occurring in an ore in square, tabular, and sometimes ex-

tremely thin crystals would cause trouble by not following the settling ratio of the specific gravity difference.

In the runs made, as indicated in Table I, the grade of concentrates in each case could have been bettered by cutting off a larger middling product or by running the concentrates that were collected over the table a second time. This was not deemed necessary when using the experimental machine, since only indicative results were desired.

Table I clearly illustrates the fact that the large wulfenite crystals—greater than 35-mesh—in association with barite are not adapted to table work, since they have a tendency to roll along with the coarse barite gangue. Wulfenite grains or crystals in this case, being approximately the same weight, due to their thin and tabular structure, as barite grains, did not have an opportunity to arrange themselves on the table according to their specific gravity differences.

In order to make a comparison of the sized runs with an unclassified ground feed, a sample of the original material was ground dry in a ball mill to pass 80-mesh; 2000 grams of this minus 80-mesh material was run over the experimental table *once*, as in runs made with screened sizes. The following table represents the results obtained:

TABLE II.

Run Made on Minus 80-Mesh Material on Wulfenite Barite Ore, Passed Once Over Table.

Sample	Wt. in grams	Per cent. Mo.	Per cent. $BaSO_4$	Per cent. recovery Mo.	Per cent. recovery $BaSO_4$
Head.....	2000	5.50	52.20		
Conc.....	508	14.32	21.14	66.20	10.28
Mid.....	338	5.76	51.10	17.72	53.01
Tails.....	726	1.86	76.20	12.28	16.55
Loss.....	428	.97*	49.20*	3.80	20.16
Footing.....	2000			100.00	100.00

* Calculated.

Table II clearly illustrates the following points:

1. That crushing in this manner does not entail any great loss of wulfenite in the slime going to waste, since only 3.80 per cent. Mo was unaccounted for.

2. That 66.20 per cent. of the wulfenite can be recovered in a concentrate of marketable grade.

3. That barite can be successfully concentrated from wulfenite, since only 10.28 per cent. of the total remained with the concentrate.

4. That the above tails and middling product, respectively, are of the same grade as the original milled ore and first middling produced and, consequently, further recovery can be made by treatment.

The results of the experiments as performed and given in Tables I and II clearly illustrate the fact that in the wet separation of wulfenite from barite, when using tables, particular attention must be given to the ore-dressing method adopted, and to the degree of grinding. Grinding at least through 48-mesh would be recommended for this class of material, as Table I indicates.

In order to determine approximately the highest grade of concentrate that can be produced from this barite middling material, 500 grams of the concentrates, assaying 14.32 per cent. molybdenum produced in experiment as given in Table II, were carefully re-run several times over the Wilfley table with the following results. No slime was produced in this treatment, so the products were easily collected and recovered.

TABLE III.

Concentration Test for High-Grade Product.

Sample	Wt. in grams	Per cent. Mo.	Per cent. recovery Mo.
Head	500	14.32	
Conc.	268	17.85	67.00
Tails	230	9.96	32.00
Loss	2		1.00
	500		100.00

The above content of 17.85 per cent. molybdenum in the concentrate represents 26.77 per cent. MoO_3. Theoretically a concentrate consisting entirely of pure wulfenite contains 39.23 per cent. MoO_3, so the above concentrate represents a grade of 68 per cent. pure wulfenite. This would then, in all probability, represent the highest grade of concentrate that could be obtained by treating such an unclassified feed of this material. The following chemical analysis of this concentrate will further emphasize this point:

ANALYSIS OF CONCENTRATE.

	Per Cent.
MoO_3	26.93
PbO	52.15
Fe_2O_3	1.03
Al_2O_3	1.19
SiO_2	3.30
V_2O_5	.65
P_2O_5	.17
As_2O_5	.90
$BaSO_4$	12.76
Cu	none
Total determined	99.08

The above analysis indicates that theoretically further concentration could be performed by elimination of the 12.76 per cent. barite and the little other gangue still remaining with the concentrate; but in practice, if this were attempted, close sizing of the feed would be required. Other lead minerals than wulfenite, vanadinite, mimetite, pyromorphite, are indicated by the excess amount of lead oxide that is required to combine with the above elements given in the analysis. The presence of both anglesite and cerrusite in the concentrate was later confirmed, but only in traces.

FLOTATION TESTS ON BARITE "MIDDLING" MATERIAL.

On this particular ore, ground through 80-mesh, flotation was attempted after giving it a sulphidizing treatment. The material was easily sulphidized by heating for a short period within a dilute sodium sulphide solution, in proportion of 10 pounds Na_2S to 1 ton of ore with a pulp ratio of 1 : 1. In treating the sulphidized material in a flotation machine, it was found on several trials with various oil mixtures and variations of factors, that the barite and wulfenite would come over with the froth in approximately the same proportion as contained in the feed. In tracing down this cause, it was found that this was due to the fact that part of the barite and the siliceous gangue matter was iron stained; and as this iron-stained material was easily sulphidized, it was carried along over with the sulphidized wulfenite, and consequently no marked separation could be made. Also it was found in performing the sulphidizing treatment that a con-

siderable amount of wulfenite was rendered soluble and, consequently, could not be accounted for in assaying the products. The results did not warrant doing any further work by flotation; therefore, this was discontinued.

CONCLUSIONS AS TO LABORATORY TESTS.

As the experimental tests were of necessity made on a laboratory scale and on very small samples of ore, the results obtained on this particular ore must be considered only as indicative of what might be expected from the treatment of commercial quantities of ore on machines of standard size, where the proper conditions for separation can be better controlled. The results from the small laboratory machine are at the best only indicative and should be regarded only in this light. Flotation was not a factor on the ore treated.

The results found with the experimental Wilfley table indicate that wulfenite can be concentrated from a barite gangue with very promising results, since on the small laboratory machine used, a recovery of between 60 and 70 per cent. of the molybdenum could be effected by passing the material only *once* over the table. It must be remembered also that a recovery had previously been made on the original milled ore of over 60 per cent., so that the additional increase obtained from the middling material, when ground through 80-mesh and with no further classification, gives a total recovery of over 85 per cent. This recovery on material that had received no special classification, outside of grinding, emphasizes further the adaptability of wet concentration methods to wulfenite ores, even with such high specific gravity gangue as barite. By a slight rearrangement of the mill circuit, wulfenite should be as readily separated from barite as from gangues of a lower specific gravity.

In conclusion, the author wishes to express his appreciation and gratitude to Dr. R. B. Moore, Superintendent of the U. S. Bureau of Mines mining experiment station at Golden, Colorado, for his valuable suggestions throughout the progress of the work.

GOLDEN, COLORADO,
U. S. BUREAU OF MINES.
September 24, 1919.

Vagrant Mines in the Atlantic Ocean.—It is well known that the belligerents, especially the English, Americans and Germans, sowed the sea with thousands of contact mines, and that many of these have drifted from their anchorage. The principal fields were the more important harbors, the British channel and the northern boundary of the North Sea. The last named mine-field was of enormous extent and density. As vagrant mines are a very serious menace to shipping, the question as to their probable course from their moorings is of great importance. It has been studied by the well-known oceanographer, the Prince of Monaco, who has for many years been investigating the direction of ocean currents. In the latter part of 1918 he presented a communication to the French Academy of Sciences (*C.V.*, v. 167, 1918, 1049) in which he exhibited a map of the principal currents in the Atlantic Ocean, and pointed out that the principal drift of the mines would be to the nearly circular sweep of waters lying between N. lat. 30° and 45°, and W. lon. 25° and 50°, being just west of Gibraltar. In September of this year he presented another communication (*C.V.*, v. 169, 1919, 562) in which he records the finding of twenty-three mines within the above indicated area, and three others in the neighborhood of the opening of the British channel. The dates of the finds ranged from November 7, 1918, to June 15, 1919. He states, as the result of his studies of ocean currents, that ships sailing between the United States and Europe will find their greatest security in a line running directly north from the mouth of the British channel to 50° N. lat. and following this to 30° W. lon., inclining towards the Newfoundland banks. The Gulf Stream marks the northern limit of danger. The ships which travel between the United States and southern Europe will find their greatest perils in the immediate neighborhood of the European coasts and in the several archipelagoes, south as far as the Canaries, and their greatest security on a line passing a little north of Madeira and tangent to the southern limit of the Saragossa Sea. H. L.

A New Drying Oil. (*Paint Mfrs. Assn. Circ.* No. 75.)—The oil of the seeds of the *Aleurites trisperma*, or soft Lumbang, a species of "candle-nut" tree, of the tropical habitat and rather limited range seems to have excellent drying properties, analogous to those of tung oil. This tree and the true "lumbang" (*A. moluccana*) grow in the Philippines, but it is stated that "soft" variety fruits in Porto Rico grow very well, and hence substantial quantities of the oil might be obtained for use in the United States. The analysis in the laboratory of the Paint Manufacturers' Association found that the Hanus method for iodine number gave very unsatisfactory results with the new oil as it does with tung oil, while the Hubl gave results comparable with those on tung oil. H. L.

FACTORS OF CLIMATIC CONTROL.*

BY

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Table IV, extended, as well as the scanty early data, mainly from the given stations, will permit, back to 1872, is graphically represented by the continuous, light curve at the bottom of Fig. 4. In 1880 and again in 1901 the curve probably does not very closely represent world-wide temperature departures, being, presumably, at both places quite too low, owing, in each case, to an abnormally cold single month in America.

TABLE IV.

Weighted Departures of Mean Temperatures from Normal Temperatures.

WORLD.

Date.	Actual.	Smoothed.	Date.	Actual.	Smoothed.
1872	−0.78	−0.30	1893	−0.34	−0.06
1873	−0.65	−0.47	1894	+0.34	+0.03
1874	+0.20	−0.34	1895	−0.21	+0.10
1875	−1.12	−0.61	1896	+0.49	+0.28
1876	−0.40	−0.60	1897	+0.34	+0.45
1877	−0.48	−0.32	1898	+0.61	+0.46
1878	+0.07	0.00	1899	+0.27	+0.59
1879	+0.33	+0.04	1900	+1.19	+0.76
1880	−0.50	−0.13	1901	+0.40	+0.55
1881	+0.14	−0.02	1902	+0.20	+0.13
1882	+0.14	−0.16	1903	−0.30	+0.10
1883	−1.04	−0.68	1904	+0.81	+0.20
1884	−0.79	−0.61	1905	−0.51	+0.01
1885	+0.17	−0.09	1906	+0.23	+0.05
1886	+0.11	+0.03	1907	+0.23	+0.30
1887	−0.29	−0.05	1908	+0.51	+0.21
1888	+0.26	+0.24	1909	−0.43	+0.11
1889	+0.74	+0.57	1910	+0.69	+0.30
1890	+0.54	+0.40	1911	+0.23	+0.09
1891	−0.21	+0.06	1912	−0.80	−0.40
1892	+0.10	−0.09			

The dotted curve from 1907 to 1911 gives the average temperature departures for the American stations only, and presumably represents world temperature departures much more closely than does the continuous light line for the same time. This is because of two or three exceptionally cold summer months in Europe.

* Concluded from p. 810, Vol. 188, December, 1919.

The dotted curve from 1872 to 1900 gives the smoothed averages of the annual temperature departures from the normal temperatures of the following stations as computed from the actual departures given by Nordmann[31]; Sierra Leone, Recife (or Pernambuco), Port au Prince, Trinité, Jamaica, Habana, Manila, Hong Kong, Zikawei, Batavia, Bombay, Island of Rodriguez, Island of Mauritius.

All these, or practically all, are low-level stations, and most of them either tropical or semi-tropical, and, therefore, should show in general, from altitude influence alone, a smaller, and from latitude influence alone, a greater, abnormality than do the stations whose temperature departures are given by the continuous fine-line curve. Hence, all things considered, the average temperature departures as calculated from the two sets of stations agree remarkably well, so that one can say with, presumably, a fair degree of confidence, that the heavy curve, T, approximately represents the average of the departures of the mean annual temperatures from the normal annual temperatures of equatorial and high altitude regions of the earth, or that T, with the above restrictions, is the curve of world temperatures.

Much additional statistical evidence bearing on this point and supporting the conclusion just given, has been published by Mielke.[32] This consists of the average annual temperatures from 1870 to 1910 of 487 widely distributed stations, with, however, numerous and extensive breaks—in fact, the records of only a few stations cover the entire period. By grouping these stations according to zones, tropical, subtropical, warm temperate, cold temperate and frigid, and then averaging and smoothing the zonal annual temperature departures, giving all equal weight, values were found which run substantially parallel to those already found but of less (about half) amplitude, quite as anticipated from the fact that stations above the dust, fogs and many clouds of the lower atmosphere must be more sensitive to variations in the transparency of the outer atmosphere and to solar changes than are those (the great majority) located at, or not more than a few hundred metres above, sea level. Either curve might, therefore, be used in a discussion of the causes and periods of temperature

[31] *Revue Générale des Sciences*, August, 1903, pp. 803–808. Annual Report, Smithsonian Institution, 1903, pp. 139–149.

[32] *Aus dem Archiv der Deutschen Seewarte*, **36**, Nov. 3, 1913.

changes, but in what follows the curve of larger amplitudes or the curve of high altitude stations will be used because: (*a*) data for it but not for the other are available through the period of the Katmai veil of dust, (*b*) it is freer from surface disturbances and therefore more representative of solar and high atmospheric conditions, (*c*) high altitude temperatures are more effective than those of sea level in modifying glacial conditions.

Relation of World Temperatures to Pyrheliometric Values.—Curve *P*, also of Fig. 4, gives the smoothed course of the annual average pyrheliometric readings, as computed from the actual values given in Fig. 1. The insolation intensity data, covering the whole of the depression that had its minimum in 1885, were obtained at a single place, Montpellier, France, by a single observer, L. J. Eon,[33] who confined himself to noon observations with a Crova actinometer. It may be, therefore, that merely local and temporary disturbances produced a local insolation curve that was not quite parallel to the curve for the entire world. At any rate, the drop in the solar radiation values obviously was due to dust put into the atmosphere by the explosion of Krakatoa in August, 1883, and it would seem that the effects of this dust both on the surface temperatures and on pyrheliometric values must have been greater during the latter part of 1883 and in 1884 than they were in 1885, when much of the dust certainly had already settled out of the atmosphere, and this supposition is well supported by the pyrheliometric and temperature drops that immediately followed the volcanic explosions of 1903 and 1912, and their partial recovery within a single year. Nevertheless, the pyrheliometric values must be accepted as obtained. Indeed, this exceptional lag is not quite unprecedented, since the coldest year following the similar, though more violent, explosion of Asamayama, just one hundred years earlier, was not the year of the explosion, 1783, nor the following year, but 1785.

It is probable that in the earlier, as certainly in the later, of these unusual cases the dust was thrown to such great altitudes that the finer portions were nearly, or quite, two years in reaching the lower level of the isothermal region. Clearly, too, much of this dust, while perfectly dry, probably was so fine as merely to scatter even solar radiation, and yet on reaching the more humid portions of the atmosphere the particles may have gathered suf-

[33] *Bulletin météorologique du Département de l'Hérault*, 1900.

ficient moisture to assume reflecting size, and, therefore, seriously to interfere with insolation. This is merely suggested, but in no wise insisted upon, as a possible explanation of the unusual pyrheliometric lag after the explosion of Krakatoa.

It is obvious, from a mere glance, that the pyrheliometric and the temperature curves, or curves P and T, have much in common. This is especially marked by the large and practically simultaneous drops in the two curves in 1912, following the eruption of Katmai. But while a relation between these curves thus appears certain, the agreement is so far from perfect as to force the conclusion that pyrheliometric values constitute only one factor in the determination of average world temperatures.

Sun-spots and Temperature.—It has been known for a long time that the curve of sun-spot numbers, curve S, Fig. 4, and the curve of earth temperatures, curve T, follow or parallel each other in a general way, in the sense that the fewer the spots the higher the temperature, with, however, puzzling discrepancies here and there. Both these facts, the general agreement between the phenomena in question and also their specific discrepancies, are well shown by the curves S and T of Fig. 4, and, while the discrepancies are marked, it is obvious that, on the whole, the agreement is quite too close to leave any doubt of the reality of some sort of connection between sun-spots and atmospheric temperatures. Just how or by what process this relation conceivably may exist will be discussed below.

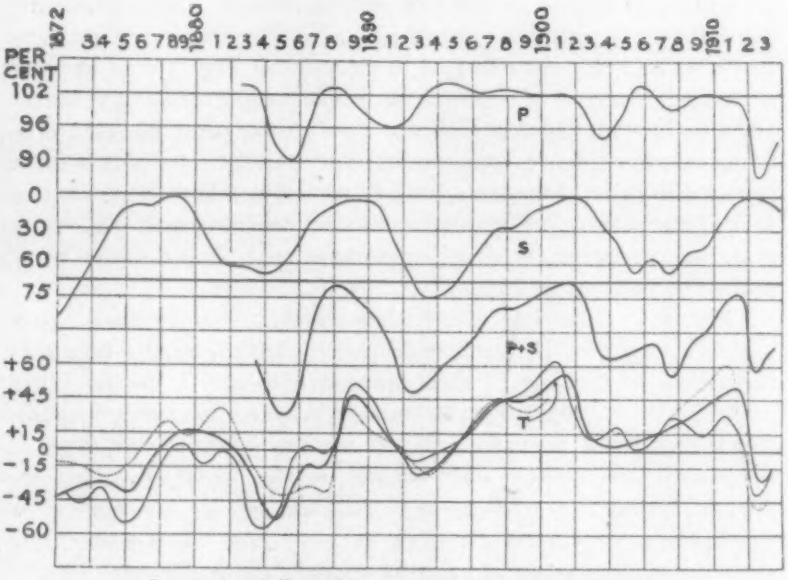
Combined Effect of Insolation Intensity and Sun-spot Influence on Atmospheric Temperatures.—Since it is obvious that the insolation intensity and the number of sun-spots each exerts an influence on the temperature of the earth, it is clear that some sort of a combination of the two curves P and S should more closely parallel the temperature curve, T, than does either alone. It is probable that the sun-spot effect is not directly proportional to the actual number of spots, but, however this may be, the direct combination of the curves P and S gives the resultant $P+S$, which, as a glance at the figure shows, actually parallels the curve of temperatures, T, with remarkable fidelity. Exactly this same combination, from 1880 to 1909, has been made by Abbot and Fowle,[34] whose lead in this important particular is here being

[34] *Smithsonian Miscellaneous Collections*, vol. lx, No. 29, 1913.

followed, and the resultant curve found to run closely parallel to the curve of "smoothed annual mean departures" of the maximum temperatures of fifteen stations in the United States.

Probably the most striking point of agreement, one that must strongly be insisted upon, as shown by Fig. 4, between the combination curve and the temperature, occurs in 1912, when, in spite of the fact that the sun-spots were at a minimum, indicating that, according to rule, the temperature should be high, the temperature curve dropped greatly and abruptly; obviously, because of the

FIG. 4.



Smoothed pyrheliometric, sun-spot, and temperature curves.

simultaneous and corresponding decrease in the intensity of solar radiation produced by the extensive veil of Katmai's dust, precisely as happened at spot minima after the explosion of Asama in 1783. Both cases, since they occurred during spot minima, show distinctly the great influence volcanic dust has on terrestrial temperatures.

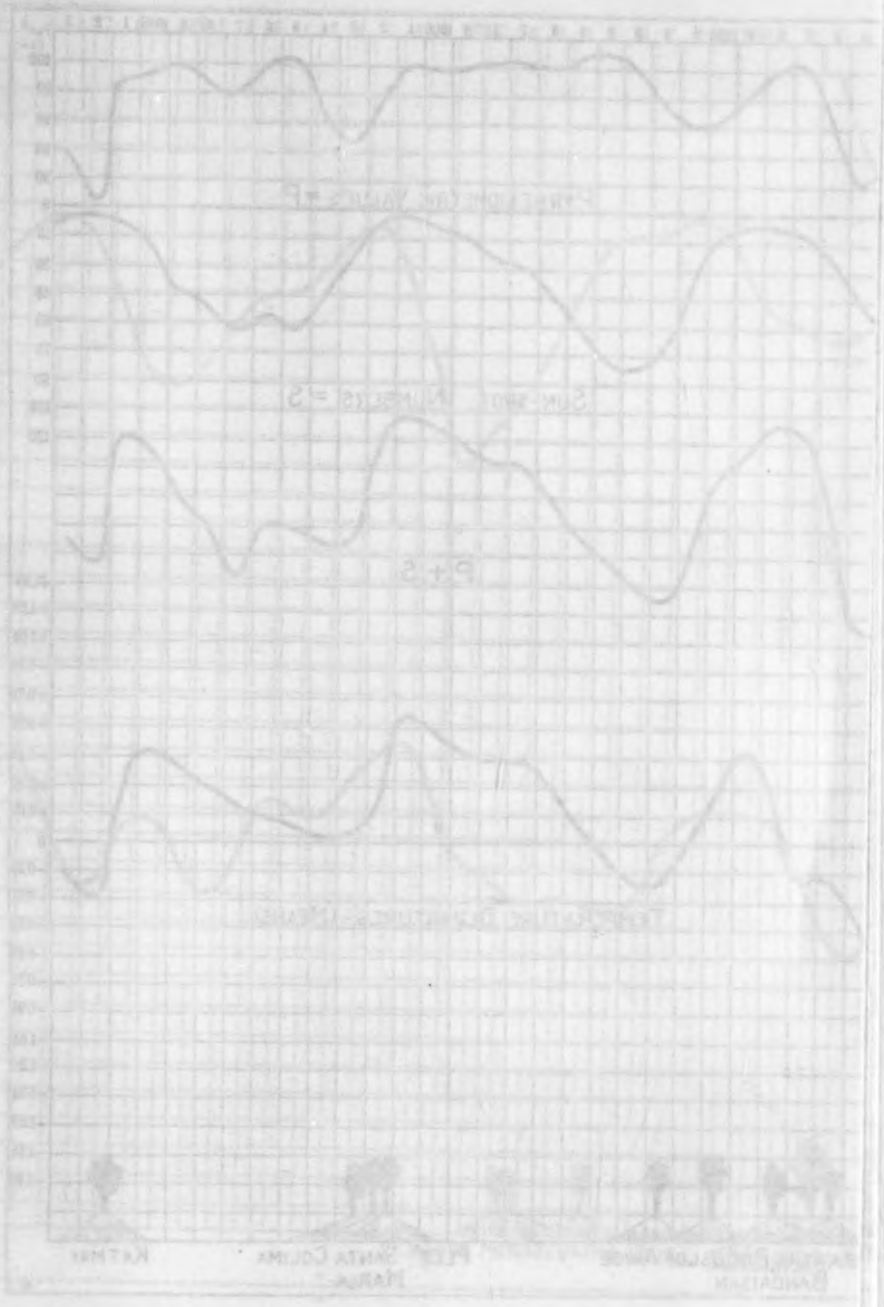
Temperature Variations Since 1750 as Influenced by Sun-spots and Volcanic Eruptions.—Sun-spot numbers[35] month by month

[35] Wolfer, *Astronomische Mitteilungen*, 93, 1902, and later numbers.

are fairly well known since July, 1749, and so, too, are the annual temperature variations[36] from about the same time, and, therefore, the data at hand for comparing these two phenomena over a continuous period of a little more than 164 years, or from at least the beginning of the year 1750 to the present date. Fig 5 makes this comparison easy. The bottom curves give the smoothed annual temperature departures, as computed from Köppen's actual annual departures, using all stations, while the top curve follows Wolfer's annual average sun-spot numbers. Of course, the earlier observations, both of sun-spots and of temperatures, were few in number and more or less unsatisfactory in comparison with those obtained during the past thirty, or even forty, years. Nevertheless, it is clear from Fig. 5 that at least since 1750, the date of our earliest records, and presumably, therefore, since an indefinitely distant time in the past, the two phenomena, atmospheric temperature and sun-spot numbers, have in general varied together, with, however, marked discrepancies from time to time. These we shall now consider, and shall show that they occurred, in every important case, immediately after violent volcanic eruptions.

Volcanic Disturbances of Atmospheric Temperature Since 1750.—It must be distinctly remembered that the earlier temperature records, because of their limited number, if for no other reason, give only the general trend of world temperatures. Again, the record back to 1750 of even violent volcanic eruptions is necessarily incomplete; and, besides, *not all great eruptions decrease the surface temperature—only those that drive a lot of dust into the isothermal region, or very high atmosphere*, and even then decrease it perceptibly in only those regions, usually extensive and at times world-wide, over which the dust spreads. Pronounced and long-continued sky phenomena, therefore, of the type that followed the eruption of Krakatoa, furnish the best evidence of volcanic violence in the sense here used. Finally, there can be no particular test save where the temperature is low in comparison with that which the number of sun-spots would indicate. Obviously, then, no matter how close the actual relation between the phenomena may be, the errors and the incom-

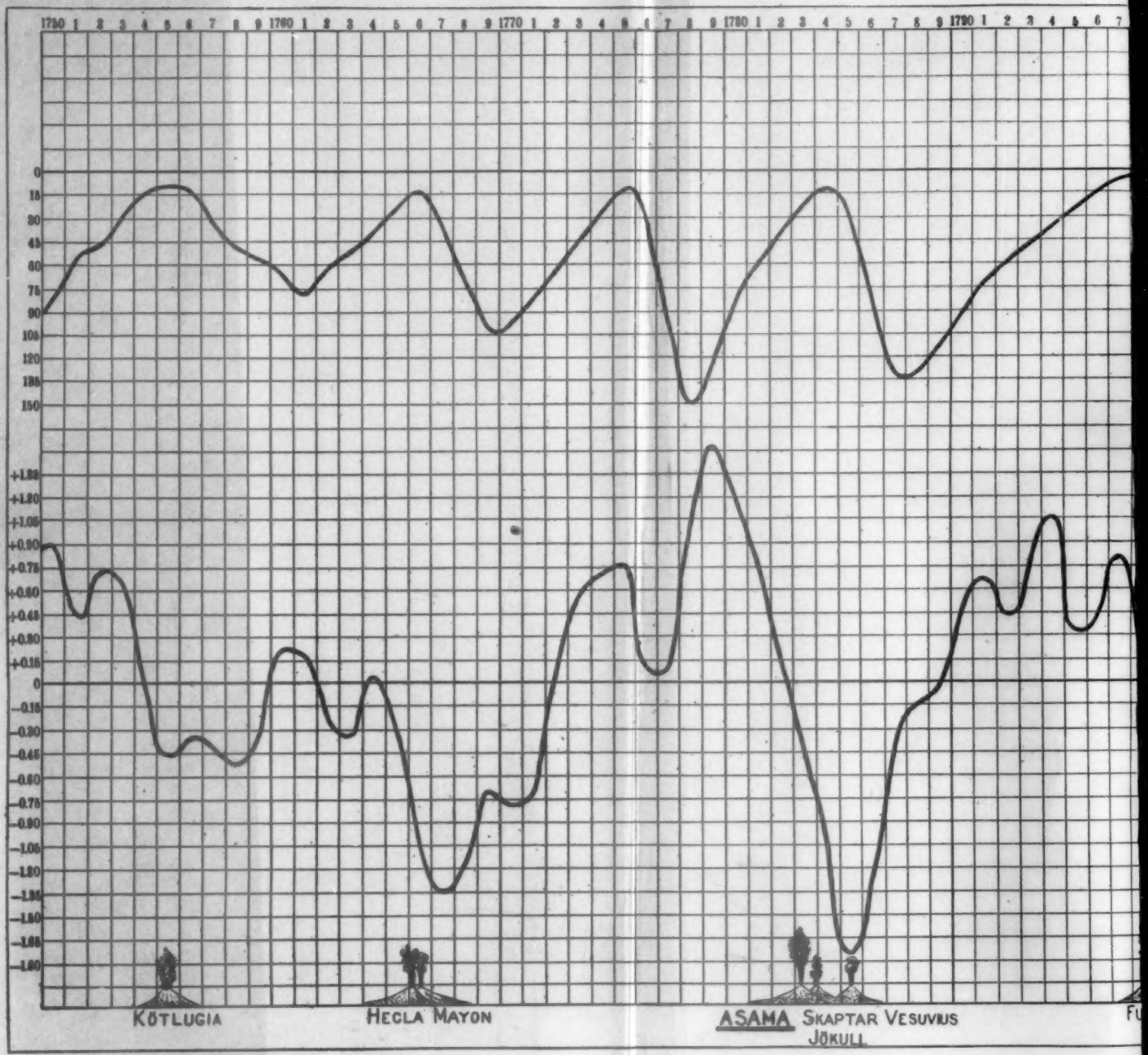
[36] Köppen, *Zeit. Oesterreich. Gesell. für Meteorologie*, vol. viii, pp. 241 and 257, 1873.



are fairly well known since July, 1749, and so, too, are the annual temperature variations[36] from about the same time, and, therefore, the data at hand for comparing these two phenomena over a continuous period of a little more than 164 years, or from at least the beginning of the year 1750 to the present date. Fig 5 makes this comparison easy. The bottom curves give the smoothed annual temperature departures, as computed from Köppen's actual annual departures, using all stations, while the top curve follows Wolfer's annual average sun-spot numbers. Of course, the earlier observations, both of sun-spots and of temperatures, were few in number and more or less unsatisfactory in comparison with those obtained during the past thirty, or even forty, years. Nevertheless, it is clear from Fig. 5 that at least since 1750, the date of our earliest records, and presumably, therefore, since an indefinitely distant time in the past, the two phenomena, atmospheric temperature and sun-spot numbers, have in general varied together, with, however, marked discrepancies from time to time. These we shall now consider, and shall show that they occurred, in every important case, immediately after violent volcanic eruptions.

Volcanic Disturbances of Atmospheric Temperature Since 1750.—It must be distinctly remembered that the earlier temperature records, because of their limited number, if for no other reason, give only the general trend of world temperatures. Again, the record back to 1750 of even violent volcanic eruptions is necessarily incomplete; and, besides, *not all great eruptions decrease the surface temperature—only those that drive a lot of dust into the isothermal region, or very high atmosphere,* and even then decrease it perceptibly in only those regions, usually extensive and at times world-wide, over which the dust spreads. Pronounced and long-continued sky phenomena, therefore, of the type that followed the eruption of Krakatoa, furnish the best evidence of volcanic violence in the sense here used. Finally, there can be no particular test save where the temperature is low in comparison with that which the number of sun-spots would indicate. Obviously, then, no matter how close the actual relation between the phenomena may be, the errors and the incom-

[36] Köppen, *Zeit. Oesterreich. Gesell. für Meteorologie,* vol. viii, pp. 241 and 257, 1873.


1750 1 2 3 4 5 6 7 8 9 1760 1 2 3 4 5 6 7 8 9 1770 1 2 3 4 5 6 7 8 9 1780 1 2 3 4 5 6 7 8 9 1790 1 2 3 4 5 6 7
0
15
30
45
60
75
90
105
120
135
150
+1.35
+1.20
+1.05
+0.90
+0.75
+0.60
+0.45
+0.30
+0.15
0
−0.15
−0.30
−0.45
−0.60
−0.75
−0.90
−1.05
−1.20
−1.35
−1.50
−1.65
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KÖTLUGIA
HECLA MAYON
ASAMA SKAPTAR VESUVIUS
JÖKULL
FU

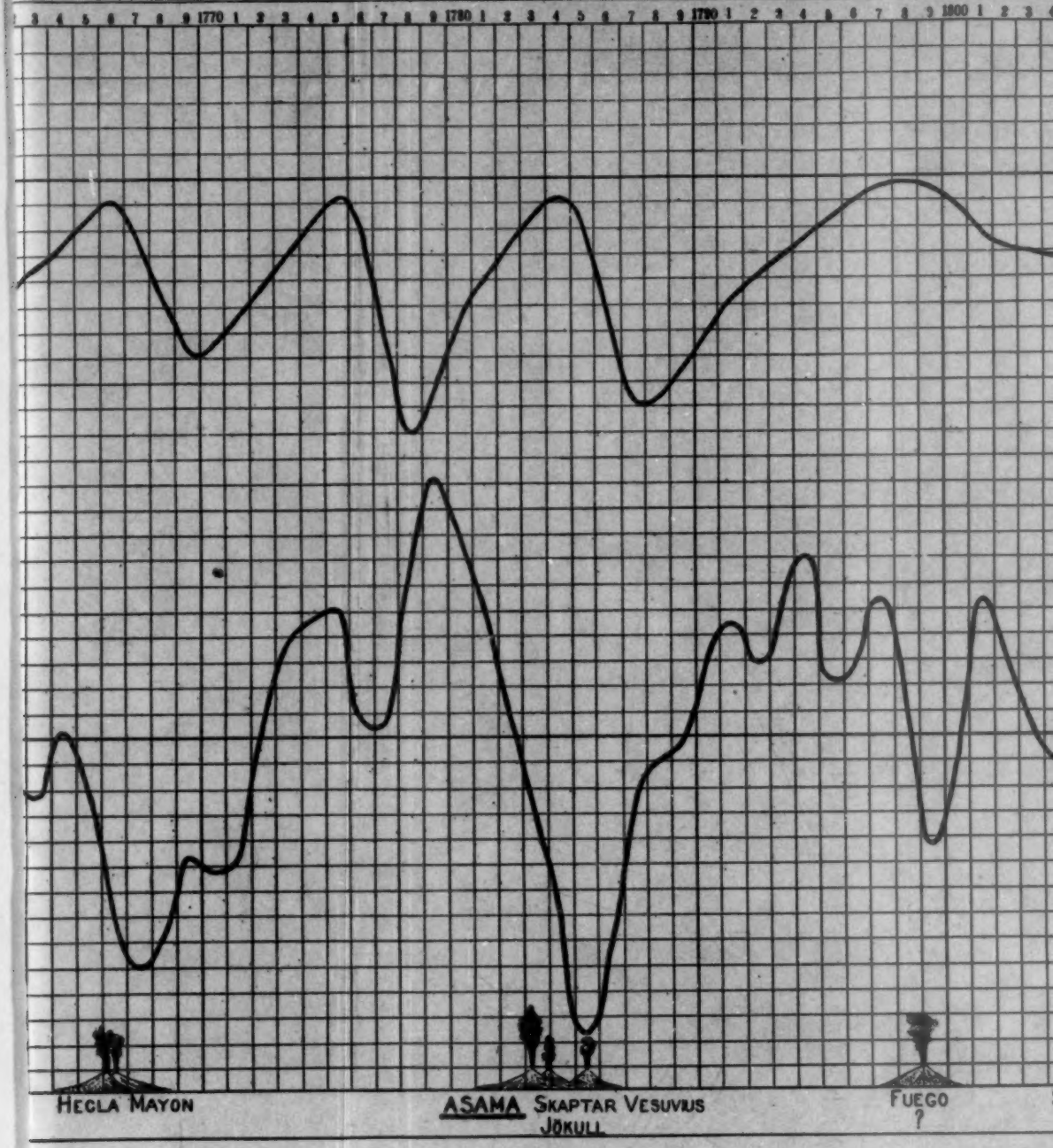
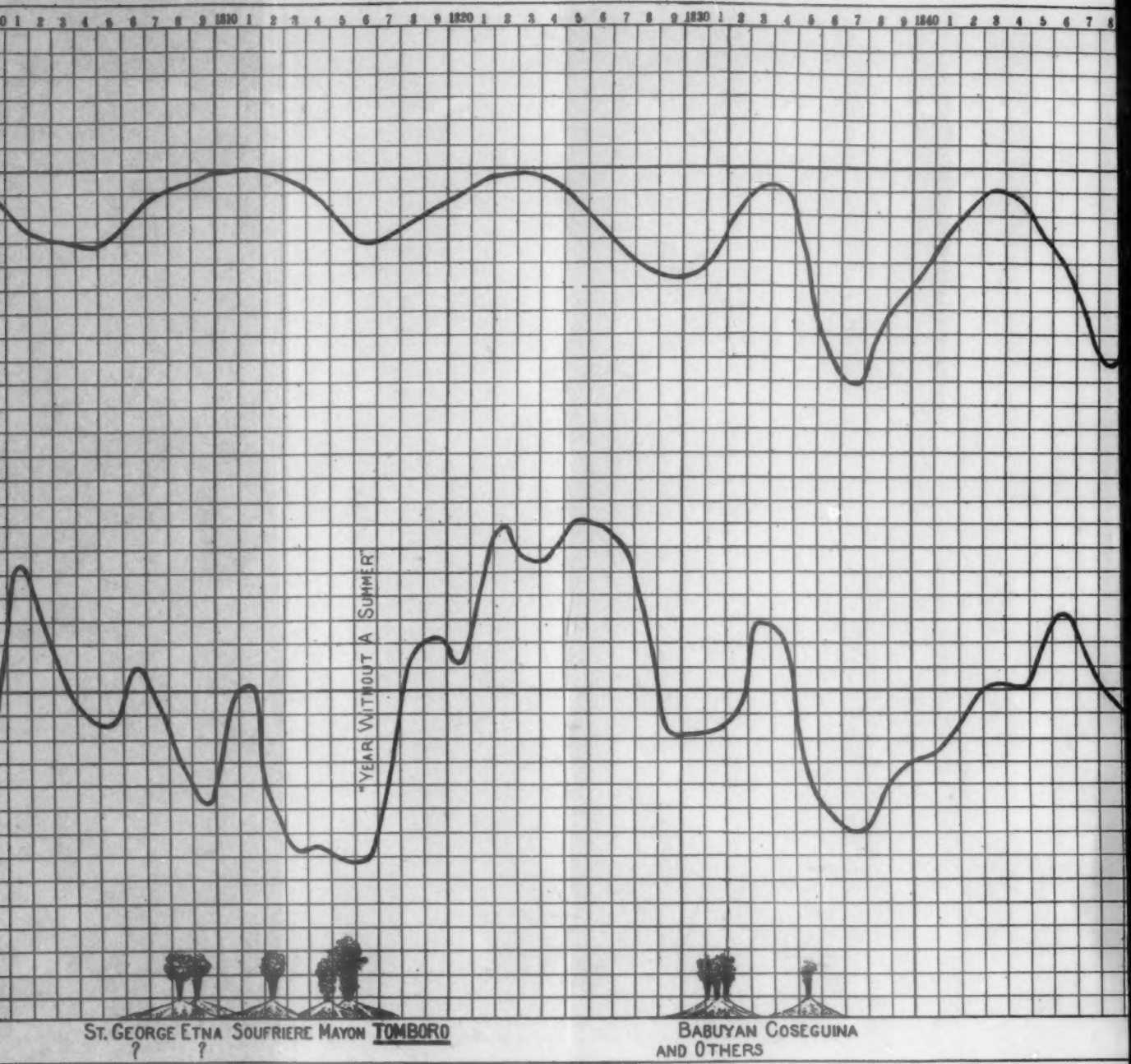
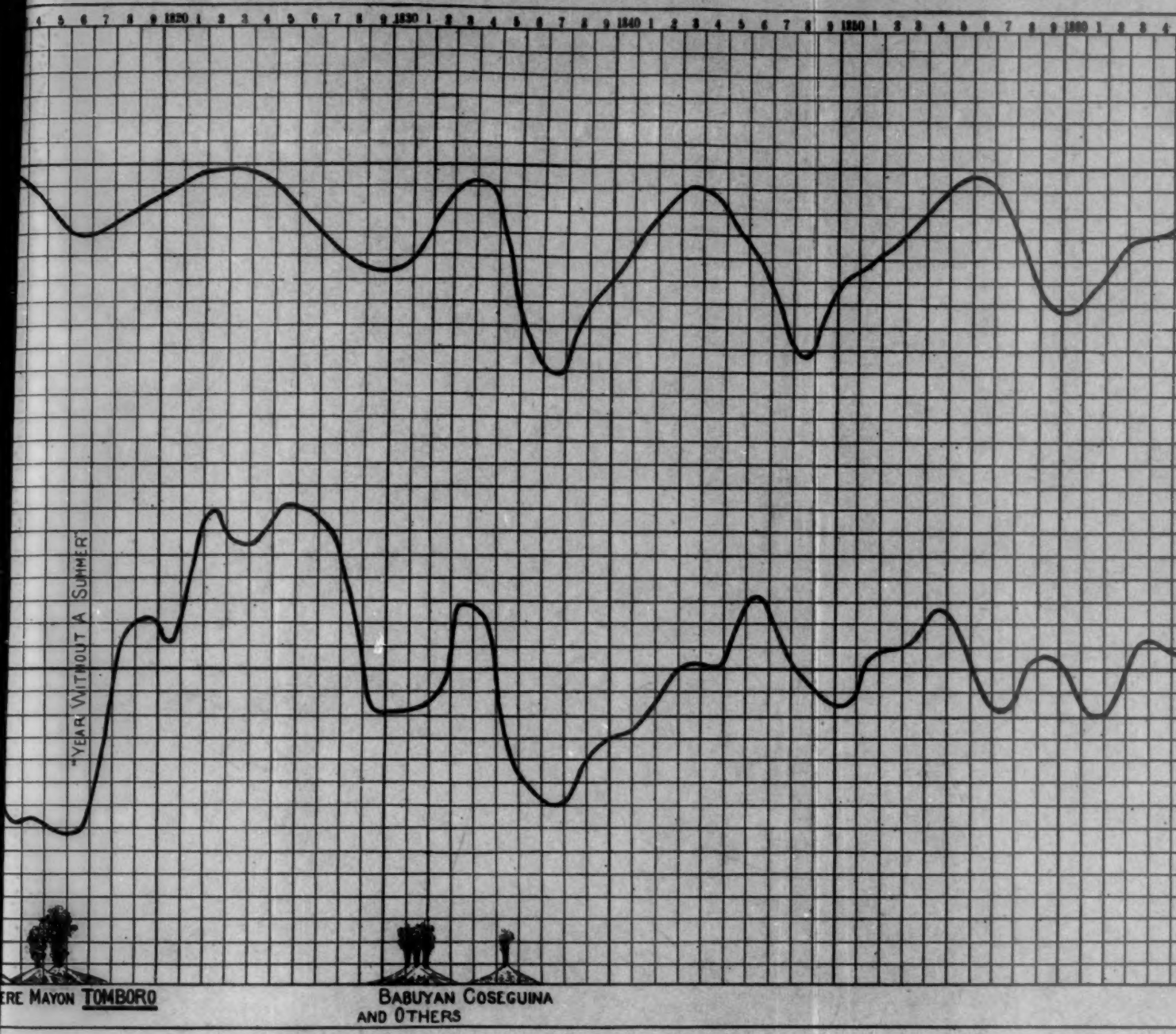

3 4 5 6 7 8 9 1770 1 2 3 4 5 6 7 8 9 1780 1 2 3 4 5 6 7 8 9 1790 1 2 3 4 5 6 7 8 9 1800 1 2 3
HECLA MAYON
ASAMA SKAPTAR VESUVIUS
JÖKULL
FUEGO
?

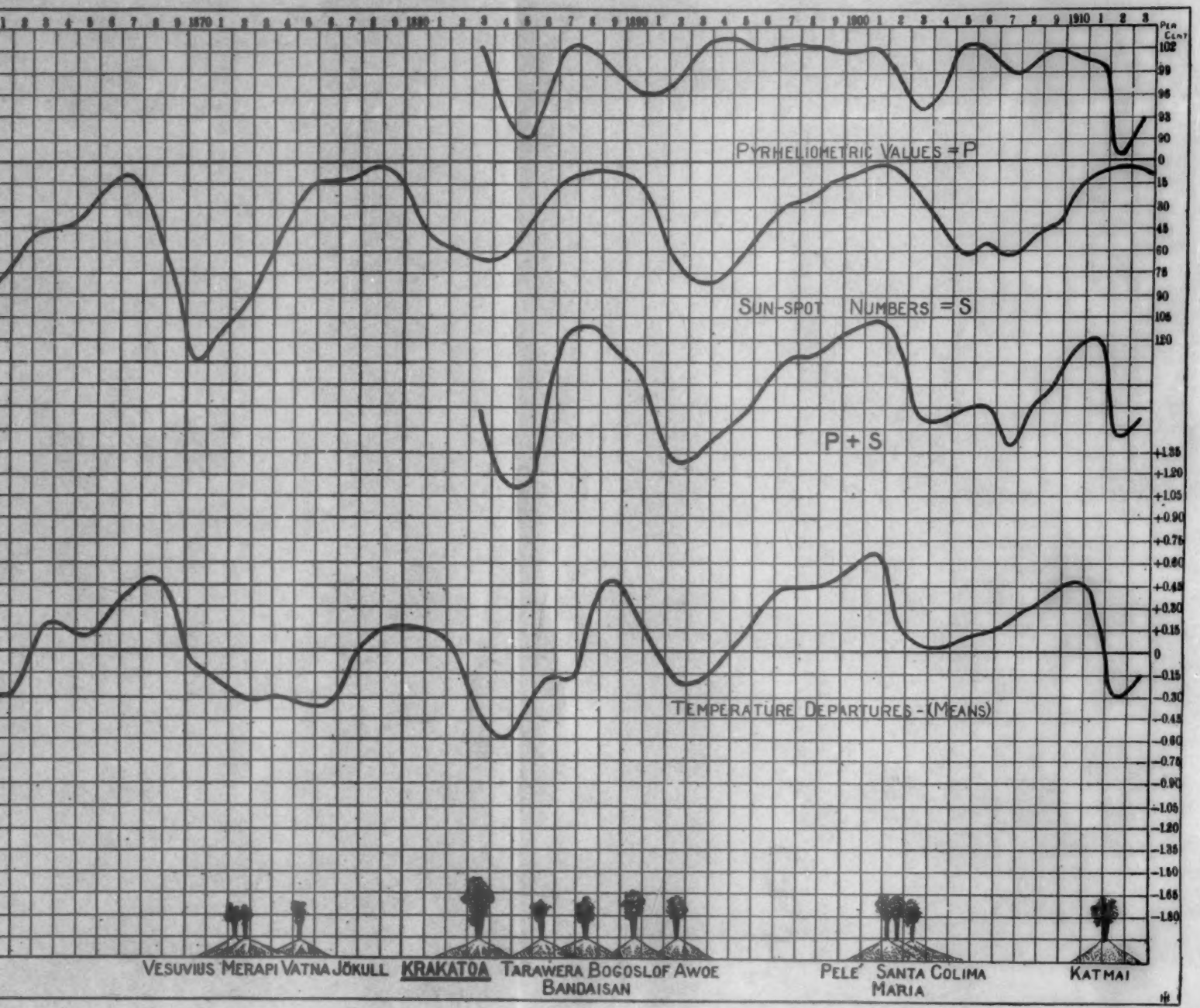
FIG. 5.

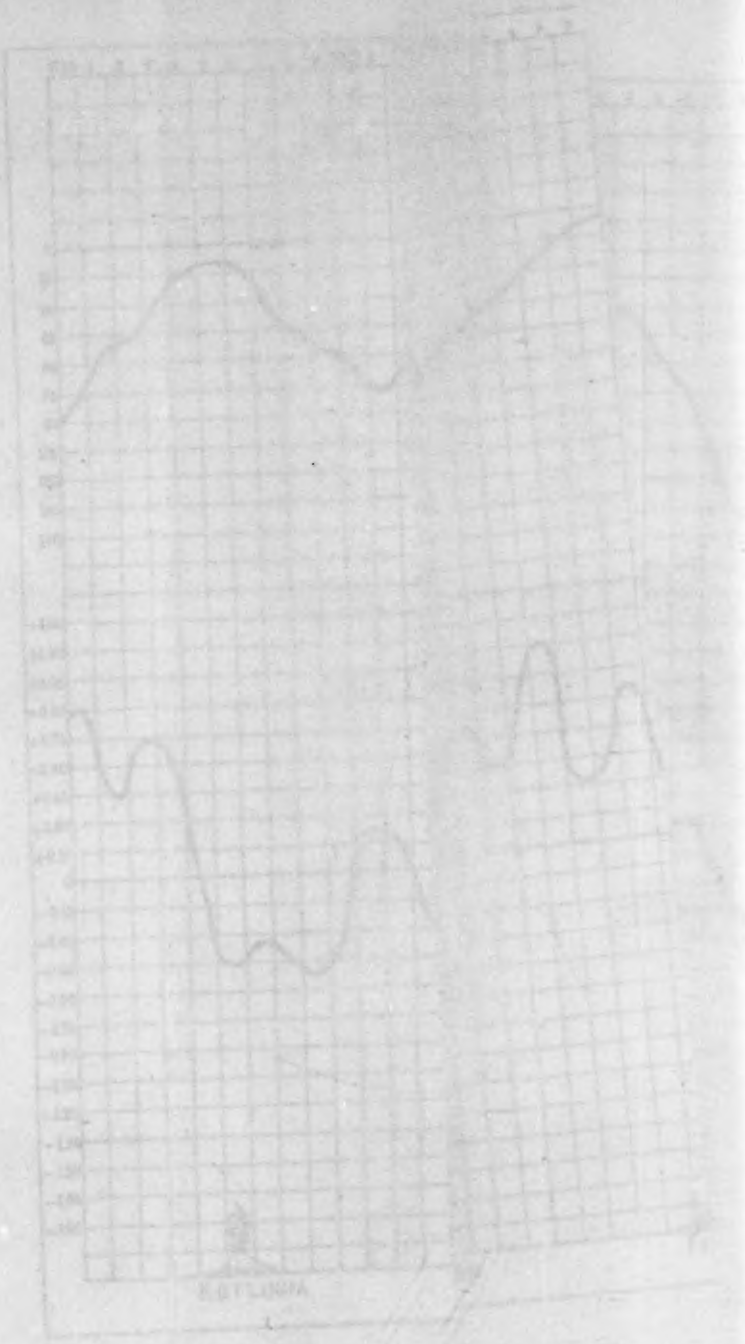

0 1 2 3 4 5 6 7 8 9 1810 1 2 3 4 5 6 7 8 9 1820 1 2 3 4 5 6 7 8 9 1830 1 2 3 4 5 6 7 8 9 1840 1 2 3 4 5 6 7 8
"YEAR WITHOUT A SUMMER"
ST. GEORGE ETNA SOUFRIERE MAYON TOMBORO
? ?
BABUYAN COSEGUINA
AND OTHERS

Relations of pyrheliometric values and mean temperature departures to sun-spot numbers and violent volcanic eruptions.



Relations of pyrheliometric values and mean temperature departures to sun-spot numbers and violent volcanic eruptions.


1870
1880
1890
1900
1910
Pyrheliometric Values = P
Sun-spot Numbers = S
P + S
Temperature Departures - (Means)
Vesuvius Merapi Vatna Jökull
KRAKATOA
Tarawera Bogoslof Awoe
Bandaisan
Pelé Santa Colima
Maria
Katmai



pleteness of the recorded data would prevent the discovery of more than a general relation.

Of course, it will naturally occur to one to ask about special cases, such as the cold years of 1783–4–5, and, in particular, 1816, the famous "year without a summer," "poverty year," or "eighteen hundred and froze-to-death." The first of these, 1783–5, followed, as already explained, the great explosion of Asama in 1783, while the second, the "year without a summer," that was cold the world over, followed the eruption of Tomboro,

Temperature and Sun-spot Discrepancies.

Date.	Nature of discrepancy.	Probable cause.
1755–6	Cold	Kötlugia, Iceland, 1755, Oct. 17.
1766–7	Cold	Hecla, Iceland, 1766. Apr. 15 to Sept. 7.
		Mayon, Luzon, 1766.
1778–9	Warm	Maximum number (annual) of sun-spots ever recorded and unusually short spot period. Can it be that the solar constant actually was notably greater than usual at this time?
1784–5–6	Cold	Asama, Japan, 1783, most frightful eruption on record.
		Skaptar Jökull, Iceland, 1783, June 8 and 18.
		Vesuvius, Italy, 1785.
1799	Cold	Fuego (?), Guatemala. (Uncertain.)
1809	Cold	St. George (?), Azores, 1808. (Uncertain.)
		Etna (?), Sicily, 1809. (Uncertain.)
1812–13–14–15–16	Cold	Soufrière, St. Vincent, 1812, Apr. 30.
		Mayon, Luzon, 1814.
		Tomboro, Sumbawa, 1815, Apr. 7 to 12, very great.
1831–2	Cold	Graham's Island, 1831, July 10 to early in Aug.
		Babujan Islands, 1831.
		Pichincha, Ecuador, 1831.
1836–7–8	Cold	Coseguina Nicaragua, 1835, Jan. 20.
		Awatska, Kamchatka, 1837.
1856–7	Cold	Cotopaxi (?), and others, 1855–6. (Uncertain.)
1872–3	Cold	Vesuvius, Italy, 1872, Apr. 23 to May 3.
		Merapi, Java, 1872, April.
1875–6	Cold	Vatna Jökull, Iceland, 1875, March 29 and during April.
1884–5–6	Cold	Krakatoa, Straits of Sunda, 1883, Aug. 27, greatest since 1783.
		Saint Augustin, Alaska, 1883, Oct. 6.
		Tarawera, New Zealand, 1886, June 10.
1890–1–2	Cold	Bogoslof, Aleutian Islands, 1890, Feb.
		Awoe, Great Sangir, 1892, June 7.
1902–3–4	Cold	Pelé, Martinique, 1902, May 8.
		Santa Maria, Guatemala, 1902, Oct. 24.
		Colima, Mexico, 1903, Feb. and Mar.
1912–13	Cold	Katmai, Alaska, 1912, June 6.

[87] Schneider, "Die Vulcanischen Erscheinungen der Erde," p. 1, 1911.

which killed 56,000 people [37] and blew up so much dust that " for three days there was darkness at a distance of 300 miles."[38]

There is a detail in the temperature curve for the years 1886–7 that needs special attention. The temporary depression where, seemingly, the temperature should be steadily rising, obviously was due to the great eruption of Tarawera (June 10, 1886), in New Zealand. This volcano is a little more than 38° south of the equator, and, therefore, furnishes a good example of an eruption on one side of the equator affecting the temperature far to the other side. Doubtless, however, when the dust gets but a little way into the isothermal region the effect is greatest on the volcano's side of the equator.

But if the temperature was decreased by Tarawera, why, one might ask, was not the pyrheliometric curve similarly affected? It was, for several months after the eruption, as the individual monthly values show,[39] but the annual means, plotted in the figure, have the effect of making the pyrheliometric disturbance from Tarawera appear only as a retardation in the recovery from the effects of Krakatoa.

Neglecting the smaller irregularities which may or may not have been of world-wide occurrence, and remembering that, other things being equal, temperature maxima are to be expected at the times of spot minima and temperature minima at the times of spot maxima, the marked discrepancies and their probable explanations may be tabulated as follows:

For the sake of completeness as well as for such little value and interest it may have the following list is added of still earlier great volcanic eruptions and the kinds of seasons that history [40] reports to have followed. Taken by themselves these ancient or preinstrumental records help but little to connect effect with cause. Nevertheless, it is at least pleasing to know that they report precisely those general weather or seasonal conditions which from later and reliable instrumental observations we infer must have happened, provided only that the explosions were sufficiently great.

Confining attention to the first of the above lists, since the value of the second in this connection is doubtful, it will be seen that excepting some ill-defined cases, all of the seeming irregu-

[37] *Rept. Krakatoa Committee Royal Society*, 1888, p. 393.

[38] *Bulletin Météorologique du Département de l'Hérault*, p. 136, 1900.

[39] Henning, *Abhand. des K. Preuss. Meteorol. Inst.*, Bd. II, No. 4, 1904.

Date of eruption.	Volcano.	Type of season, etc.
79, Aug. 24.....	Vesuvius. (Destruction of Pompeii.)	About 80, severe drought for several years in middle Asia. (Accords with low temperature but signifies very little.)
1631, Dec. 16.....	Vesuvius. (Most violent since 79. Height of ash cloud, measured by Braccini, 48 kilometres.)	1632, Apr. 27, destructive snow in Transylvania (Siebenbürgen); May 17, frost in Saxony; hot dry summer in Italy; Oct. 4, very cold in France, 37 soldiers frozen between Montpellier and Baziers. 1633, severe winter; May 22, snow and severe cold in Transylvania.
1636, May 18 to winter	Hecla.....	1637, long, severe winter.
1680.....	Celebes.....	1681, severe drought and cold spring (Evelyn's Diary).
1693, Feb. 13 till Aug.	Hecla.....	1694, hard, snowy winter in both Italy and Spain; May 17, all vineyards of Troyes destroyed by frost.
1694.....	Celebes.....	1695, long, severe and dry winter; cool summer.
1694.....	Amboyna.....	
1694, Nov. 20 till 1695, April.....	Gunong Api.....	
1707, May 20 to Aug.	Vesuvius.....	1708, very mild winter; cold summer; Dec. 10 to 20, very heavy snow in France.
1707.....	Japanese volcano	1709, from Jan. 6, for a month and a half extraordinary severe cold in nearly all Europe; Adriatic Sea and Thames frozen; snow 10 feet deep in Spain and Portugal; 50 days frost in England from Dec. 25, 1708 till March 12, 1709; mild winter in Constantinople, but very severe in eastern North America; May 17, snow in Oedenburg; May 17 and 18, frost in Alsace; cool, rainy summer.
1707, May 25 and July 25	Santorin.....	
1721, May 11 till autumn	Kötlugia.....	1722, cool, wet year.

larities in the temperature curve, and all of the known volcanic eruptions, are satisfactorily accounted for.

It may be concluded, therefore, that the variations in the average temperature of the atmosphere of the kind and magnitude shown by actual records depend jointly upon volcanic eruptions, through the action of dust on radiation, as already explained, and upon sun-spot numbers, through, presumably, some intermediate action they have upon the atmosphere—possibly of the nature explained in the next chapter.

Magnitude and Importance of Actual Temperature Changes.—The actual temperature range from sun-spot maximum to sun-

spot minimum varies, roughly, from 0.5° C. to 1° C., or possibly more, while the effect of volcanic dust appears to be fully as great—on rare occasions even much greater. In some ways, and in respect to many things, a range of average temperatures of even 1° C. is well-nigh negligible, and, therefore, however important the results may seem to the scientist, the ultra-utilitarian would be justified in asking, "What of it?"

Much of it, in a distinctly practical as well as in a purely scientific sense, as is true of every fact of nature. For instance, during the summer, or growing season, a change of 0.5° C. produces a latitude shift of the isotherms by fully 80 miles. Hence, if there is but little or no volcanic dust to interfere, during sun-spot minima cereals and other crops may be successfully grown 50 to 150 miles farther north (or south in the southern hemisphere) than at the times of sun-spot maxima. This alone is of great practical importance, especially to those who live near the thermal limits of crop production.

In addition to changing the area over which crop production is possible, a change of average temperature also affects, in some cases greatly, the time of plant development. Thus Walter [41] has shown that a change of only 0.7° C. may alter, and in Mauritius has been observed actually to alter by as much as an entire year, the time required for the maturing of sugar cane. Hence the temperature changes that normally accompany sun-spot variations, though small in absolute magnitude, are of great importance, and, by availing ourselves of the reasonable foreknowledge we have of these changes, may easily be made of still greater importance.

In forecasting these small but important climatic changes it must be distinctly remembered that to the fairly periodic, and therefore predictable, sun-spot influence must be added the irregular and unpredictable volcanic effects. But even here the case is not bad for the forecaster, because the volcanic dust always produces, qualitatively, the same effect—a cooling—and because both the amount of this cooling and its duration (generally only one or two years, as already explained) may approximately be estimated from the nature of the volcanic explosion itself.

[41] "On the Influence of Forests on Rainfall and the Probable Effect of 'Déboisement' on Agriculture in Mauritius" (1908).

CHAPTER V.

OTHER FACTORS OF CLIMATIC CONTROL.

(9, 10, 11, 12, 13, 14.)

9. SUN-SPOTS.

As already stated, the average temperature of the earth as a whole varies inversely with the frequency of sun-spots.

How Sun-spots May Change Earth Temperatures.—If the solar constant should remain the same from spot maximum to spot minimum it clearly would not be easy to see at a glance why the surface temperature of the earth should vary as it does with spot numbers; and the situation is still more difficult if, as observations appear to indicate, the lowest temperatures occur when the solar constant is greatest and the highest temperatures occur when this constant is least. There is, however, a possible explanation of the paradox, and, while it may not contain the whole truth, it nevertheless is sufficient to show *a priori* that in all probability our temperatures do change from spot maxima to spot minima without a corresponding change in the solar constant, and also to show that a decrease in our surface temperatures may accompany even a slight increase in the solar constant.

The explanation in question has already been given elsewhere,[42] and the original paper must be consulted by those who wish to weigh all the details of the argument. Briefly, however, the argument is as follows:

1. At the times of spot maxima the solar corona is much more extensive than it is at the times of spot minima—a well-known observation.

2. This corona consists, in part at least, of reflecting particles, as many eclipse observations have shown, and so may be regarded as dust in the solar atmosphere.

3. The brightness of the sun, as every solar observer knows, drops off from centre to limb.

4. This drop, as reported by various observers, is greater the shorter the wave-length, and due, almost certainly, to diffuse scattering.

From the observational facts it follows that during spot

[42] Humphreys, *Astrophys. Jr.*, 32, p. 97, 1910.

minima, other things being equal, the solar spectrum must necessarily be richer in violet and ultra-violet radiation than it is during spot maxima.

But, as experiment has shown,[43] ultra-violet radiation of shorter wave-length than λ 1850 is strongly absorbed by oxygen, with the result that some of the oxygen is converted into ozone. Hence, since the atmosphere of the isothermal region is cold and dry (conditions favorable to the stability of ozone) and since of the gases of the upper atmosphere only oxygen is appreciably absorptive of radiations between λ 1250 and λ 1900[44] the stratosphere was believed to contain more or less ozone, a belief now fully confirmed by several observers,[45] and long ago virtually confirmed by Ångström.[46] In so far, then, as this ozone is produced by the action of ultra-violet solar radiation, it is also logical to expect it to be greater in quantity when the short wave-length radiation, to which it is due, is most intense, or, presumably, therefore, at the times of spot minima. Now, according to the experiments of Ladenburg and Lehmann,[47] while ozone is somewhat absorptive of solar radiation it is several-fold more absorptive, in fact, highly absorptive, of terrestrial radiation. Hence, in this case, as in the case of the absorption of radiation by dust, already considered, equation *A* is applicable.

In this equation let *a* be the coefficient of absorption of the ozone in the isothermal region for solar radiation, and *b* its coefficient of absorption for earth radiation. To be definite, let $a = 0.02$ and $b = 0.10$ at the time of spot maximum, and for a spot minimum let $a = 0.03$ and $b = 0.15$, quantities that would require really very little ozone. Then, since the earth radiates practically as a full radiator, or black body, at the absolute temperature 256° C., if *T max.* and *T min.* are the equilibrium temperatures at the time of spot maximum and spot minimum, respectively,

$$\left(\frac{T\,\text{max.}}{256}\right)^4 = \frac{521}{500};\ T\,\text{max.} = 258°.65$$

[43] Lyman, *Astrophys. Jr.*, **27**, p. 87, 1908.

[44] Lyman (*l. c.*).

[45] Fabry and Buisson, *C. R.*, **156**, p. 782, 1913; *Journal de Physique*, **3**, p. 196, 1913; Fowler and Strutt, *Proc. Roy. Soc. A.*, **93**, p. 577, 1917; Fowle, *Smithsonian Miscellaneous Collections V.*, **68**, No. 8, 1917.

[46] *Arkiv för Matematik, Astronomi och Fysik*, **1**, p. 395, 1904.

[47] *Annalen der Physik*, **21**, p. 305, 1906.

and

$$\left(\frac{T\,\text{min.}}{256}\right)^4 = \frac{2129}{2000};\ T\,\text{min.} = 260°.05$$

That is, under these conditions, and if the solar constant should remain exactly the same, the temperature at the time of spot minimum would be 1°.4 C. warmer than at the time of spot maximum. Hence, even a slight increase in the solar constant at the time of spot maximum might still leave the temperature a trifle cooler than at the time of spot minimum.

Obviously, too, a greater extent of cirrus and cirrus haze during spot maxima than during spot minima (a condition some observers have thought to exist; and due, perhaps, if it does exist, to auroral effect) would also tend to produce the concurrent temperature difference.

Of course, it is not asserted that either the ozone, or the cirrus haze, actually does vary in the manner assumed—observations are inadequate to decide either question; but as such changes are in complete accord with laboratory experiments, it seems that the possibility of their occurrence in nature, and their effects, should be mentioned.

INFLUENCE OF CARBON DIOXIDE ON TEMPERATURES.

It was stated in the early part of this discussion, under the carbon dioxide theory of ice ages, that the question of the possible effect a change in the amount of carbon dioxide in the atmosphere might have on temperatures would be taken up later. The way to this is now open through the above discussion of ozone. Like ozone, carbon dioxide also is more absorptive of terrestrial radiation than of solar energy. Hence, increasing the carbon dioxide in the atmosphere, and thereby increasing its amount in the isothermal region where it can be treated as a shell external to the radiating earth, obviously must have the same general effect on the temperature of the earth as increasing the ozone of this region would have. That is, other things being equal, a greater or less temperature increase would follow the introduction into the atmosphere of a larger amount of carbon dioxide.

Because of the constant mixing caused by vertical convection, it is probable that the percentage of carbon dioxide is very nearly as great at the under surface of the isothermal region as it is at the surface of the earth. If so, then the carbon dioxide of the

isothermal region is equivalent, roughly, to a layer 40 centimetres thick at normal atmospheric pressure. In high latitudes, where the isothermal level is low, the equivalent layer probably is thicker than this, and in equatorial regions probably thinner. Now, according to the experiments of Schlaefer,[48] a layer of carbon dioxide 40 centimetres thick is sufficient to produce very nearly full absorption, and, therefore, no increase in the amount of carbon dioxide in the atmosphere could very much increase its temperature.

An approximate idea of the possible temperature change of the lower atmosphere as a result of the presence of carbon dioxide in the isothermal region can be obtained from known data. Thus, Abbot and Fowle [49] have computed that carbon dioxide may absorb 14 per cent. of the radiation from a black body at the temperature of 282.2°, C. absolute. But as this is not many degrees, 25 or so, above the effective temperature of the earth as a radiator, it follows that 14 per cent. is, roughly, the upper limit to which terrestrial radiation can be absorbed by carbon dioxide in the isothermal region, while its absorption of solar radiation is very nearly negligible.

Assuming that the present amount of carbon dioxide in the isothermal region absorbs 1 per cent. of the solar radiation and 10 per cent. of the outgoing earth radiation (values that seem to be, roughly, of the correct order), and using equation *A*, it will be seen, if the experiments here referred to and the assumptions are substantially correct, that doubling or even multiplying by several-fold the present amount of carbon dioxide, which would leave the absorption of solar radiation practically unchanged, and increase the absorption of terrestrial radiation at most to only 14 per cent., could increase the intensity of the radiation received at the surface of the earth about half of 1 per cent., and, therefore, the average temperature by no more than about 1.3° C. Similarly, reducing the carbon dioxide by one-half could decrease the temperature by no more than approximately the same amount, 1.3° C.

It is not certain to what extent the percentage of carbon dioxide in the atmosphere has actually varied during the geologic past, but, if the above reasoning is correct, it seems that surface

[48] *Ann. der Physik*, 16, p. 93, 1905.

[49] *Annals Astrophys. Obsy., Smithsonian Inst.*, vol. ii, p. 172, 1908.

temperatures could never have been much increased above their present values through the action of this particular agent alone. Furthermore, the fact, so far as known, that within the tropics, at least, plant growth was quite as vigorous during the ice ages as it is now, shows that for a very long time, even in the geological sense, carbon dioxide has been abundant in the atmosphere—probably never much less abundant than at present. Hence, it seems likely that a decrease in temperature of a fraction of one degree is all that can reasonably be accounted for in this way.

Finally, if the above reasoning is correct, it seems that changes in the amount of carbon dioxide in the atmosphere might have been a factor in the production of certain climatic changes of the past, but that it could not, of itself, have produced the ice ages.

10. LAND ELEVATION.

Since many changes in land elevation are known to have taken place during the different geologic ages it is necessary, in considering the climates of the past, to inquire what climatic effects such variations in level would of themselves produce. Changes in area will be considered later.

The substantial answer to this question obviously is found in the present effects of elevation on climate. That is to say, the effects of elevation must then have been distant, local, and universal, just as they now are. The distant effects obviously often extended, as they now extend, many hundreds of miles to the leeward of favorably situated high mountain ranges and consisted, as they now consist, essentially in a decrease of precipitation, owing to the extraction of moisture from the atmosphere by forced convection and the consequent tendency towards, or even culmination in, desert conditions beyond. The second or local effects clearly were both an increase in the local precipitation, especially on the windward side, and an average decrease in the temperature, approximately the same as at present,[50] of about 1° C. for each 180 metres, 200 metres, and 250 metres difference in elevation on mountains, hills and plateaus, respectively.

In one important case, namely, when the surface is extensive and snow-covered (probably to some extent also when bare), this relation of temperature decrease between mountain, hill and plateau does not hold, as is obvious from the following considera-

[50] Hann, "Lehrbuch der Meteorologie," 2nd ed., p. 101.

tion. During long, clear winter nights, such as obtain in high latitudes, the surface becomes greatly chilled through comparatively free radiation to the still colder air far above and even to empty space beyond. Hence, the surface air also is chilled and its density made correspondingly greater. It, therefore, flows away to lower levels and at the same time its temperature is increased through increase of pressure, or at least prevented from falling so low as it otherwise would. When the slope is steep, as it usually is on the sides of hills and mountains, this flow clearly must be more or less rapid, especially along narrow valleys or ravines, and, therefore, an approach established, within this portion of the air current, to the adiabatic temperature gradient of about 1° C. per each 100 metres' change in elevation. On the other hand, when the slope is very gentle, as it is over the interior of Greenland and over much of the explored portion of the Antarctic Continent, air drainage necessarily is sluggish and unable to keep pace with the surface cooling. Hence, in such cases the change of temperature with change in elevation (counting from sea level) can be, and usually is, far greater than adiabatic, or 1° C., about, per 100 metres. Hence, such regions, when there are no higher surrounding mountains, can and often do establish: (1) a circulation of the upper air from the ocean to the higher portions of the plateau; (2) a well-defined surface temperature inversion, or, for the first few hundred metres, an increase of temperature with increase of elevation; (3) a slow settling of this air onto the cold surface below; (4) the precipitation, without cloud, of fine snow crystals—" frost snow "; (5) drainage of this chilled and relatively dense air to lower levels; (6) drifting of the snow with the winds and the consequent extension, so far as temperature and other conditions will permit, of the ice-covered or glaciated area.

All these conditions obtain to-day over the two great glaciers that still remain, that of Greenland and that of Antarctica, and, presumably, therefore, must also have obtained to a greater or less extent over all great glacial fields wherever and whenever found. Mere changes in level, therefore, might cause, and doubtless often have caused, somewhat corresponding fluctuations in the climates of both local and leeward regions, and especially in the extent and depth of local glaciations; but this obvious fact does not in the least justify the assumption that either the universal

low temperatures and extensive glaciations of ice ages or the world-wide genial temperatures of the intervening periods had, on the whole, any such origin.

It may be worth while in this connection to call attention to the fact that the thickness or depth of a glacial sheet cannot continue indefinitely to increase with increase of elevation, but, on the contrary, for each given locality must have a level of maximum development, above which it somewhat rapidly decreases.

An important if not the chief contributing factor to this result is the relation of saturation to temperature, illustrated by Fig. 6, which shows by its shaded areas the relative amounts of precipitation for each 5-degree decrease in the temperature of saturated air, assuming the volume to remain constant. Now, as the wind blows up and over a mountain range its temperature decreases somewhat regularly with increase of elevation, and, therefore, at whatever temperature precipitation begins it must, as Fig. 6 shows, continue to decrease in amount as the cloud reaches higher and higher elevations—the effect of the accompanying volume increase on vapor capacity being much less than the effect of the temperature decrease.

If the precipitation always began at the same level, it is obvious that this would be the level not only of initial but also of maximum precipitation. But as the level of initial precipitation actually varies through a considerable range, it follows that the level of maximum catch lies somewhere within this range, probably, too, well within its lower half. Obviously, then, the level of maximum snowfall is not at, nor even close to, the tops of very high mountains, but far down near the lower snow limit.

In addition to this, the generally increasing steepness of the higher reaches causes more frequent avalanches and a greater speed of flow. In short, the higher mountain levels not only catch less snow than do the somewhat lower, but also more rapidly shed what they do catch.

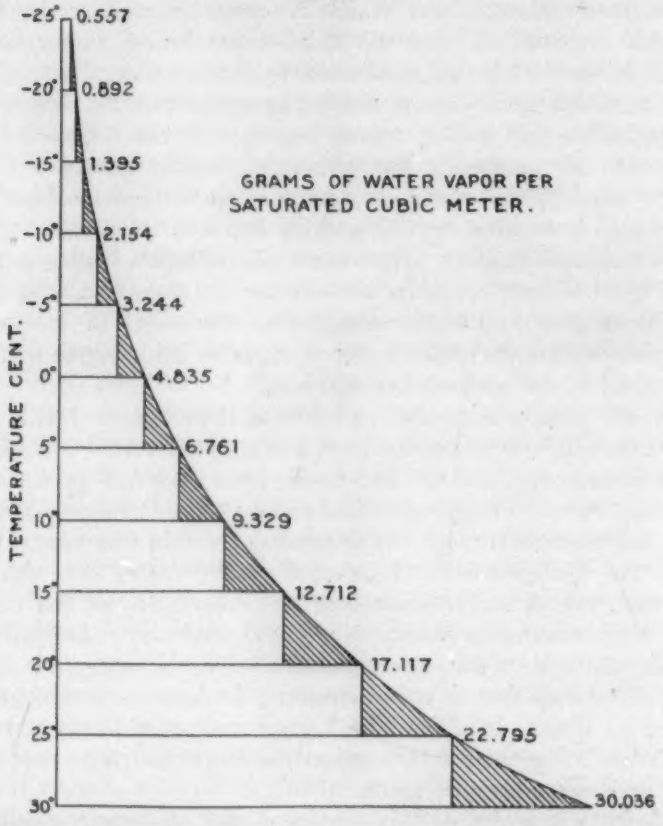
A full discussion of this subject would, of course, require an account of the rate of melting, evaporation, drift, glacial flow, and probably other phenomena; but the above, presumbaly, is sufficient to make it clear why maximum glaciation is not at the greatest elevations, but, on the contrary, at distinctly lower levels.

The universal climatic effect of land elevation, mentioned above, a greater or less lowering of the average temperature over,

perhaps, the entire earth, is a logical consequence of the other two. As is well known, water vapor is by far the world's greatest conservator of heat. Hence, anything that diminishes the average amount of this substance in the atmosphere obviously must somewhat lower surface temperatures.

Now precipitation through which the average humidity is

FIG. 6.



lowered is induced chiefly by vertical convection, a condition which mountain ranges vigorously and extensively produce, (*a*) by mechanical deflection of the winds, (*b*) by updrafts induced on their sides during summer insolation, and (*c*) by the air drainage down their valleys of clear nights. The first two types of convection are very efficient in removing moisture from the

atmosphere, while the third spreads the cold of the exposed higher levels—exposed in the sense that they are above much of the protecting vapor blanket, and, therefore, subjected to more rapid cooling.

Clearly, then, assuming the same total extent of land area, the average temperature of the world is lower when there are a number of high mountain ranges than when there are but few or none—lower because the exposed heights themselves are cold, because they drain their cold air over adjacent regions, and because they dry the atmosphere and thus prevent other portions of the earth from having as efficient protection from heat loss as they otherwise would.

This lowering of the average temperature necessarily decreases the rate of evaporation and the saturation quantity, and, thereby, presumably, further accentuates the cooling. Hence, high mountain ranges, especially when along the coasts of extensive continents, lead to low temperatures, local and windward glaciation, and reduced leeward precipitation. On the other hand, the absence of mountain ranges permits of a relatively humid atmosphere and comparatively high average temperatures.

Conceivably, therefore, the great world-wide climatic changes of the past originated in corresponding changes of level, gradual or cataclysmic. Nevertheless, it seems most improbable (apparently it has not yet been definitely proved one way or the other) that all the several glaciated continents rose and sank together—that there neither is, nor ever was, a simultaneous swing, up and down, of all, or nearly all, continental areas on the one hand and ocean beds on the other; at least not to any such extent as this hypothesis would demand. To be sure, there is much and increasing evidence [51] that in geologically very recent times there has been an increase of sea level relative to that of the land of, roughly, 50 metres in many tropical and subtropical regions where, so far as known, glaciers have never existed. But the simplest interpretation of this appears to be, not that so extensive and such different ocean beds have everywhere sunk to substantially the same extent and at about the same time, but rather that the phenomenon is only the inevitable result of the melting of the extensive glacial sheets of the Quaternary ice age.

[51] Vaughan, *Bull. Amer. Geographic Soc.*, vol. xlvi, p. 426, 1914; Daly, *Amer. Jr. Sci.*, 41, 153, 1916.

It will be assumed, therefore, that all effects, of whatever kind, changes in land elevation may have had on climate, local and leeward, were essentially as above explained, and hence that such changes, however important as contributory factors, constituted neither the sufficient initiating nor the whole sustaining cause either of the glacial or of the interglacial climates if, as is generally believed, these were simultaneously world-wide.

11. CHANGES IN LAND AREA.

In addition to changes in land elevation, and largely because of such changes, there have also been many variations in land extent and, consequently, in the ratio, both local and world-wide, of water surface to land surface. The importance of this phenomena may be inferred from the fact that, according to Schuchert,[52] North America alone has been submerged at least 17 times over areas that range from 154,000 to 4,000,000 square miles, or fully half its present extent. Hence, in a discussion of how the climates of the past have varied, and why, it is necessary to take this additional factor into consideration. An exact or quantitative evaluation of this factor is impossible, but its qualitative effect, and even a rough approximation to its numerical value, may be inferred from the present climates, along the same latitudes, of continents and of islands, and also from the climatic contrast between the northern and the southern hemispheres, as shown in Fig. 8, by the mean annual isotherms. That is, any appreciable increase in the ratio of land to ocean surface presumably accentuated the seasonal contrasts, or made the summers warmer and the winters colder than they otherwise would have been. It must also have accentuated the latitude contrast or made warm regions warmer and cold ones still colder, as is also illustrated by Fig. 8. In short, any increase of land area must, in general, have rendered the local climate more continental and less marine, and all this for the obvious reason that while the solid portions of the earth, rock, sand and soil have no power of avoiding great temperature ranges through either evaporation, convection or flow to other latitudes, all three methods belong abundantly to the ocean.

From this, in turn, since the range of animal species is partly restricted and delimited by the extremes of temperature, and the

[52] *Bull Geol. Soc. America*, vol. xx, p. 601, 1910.

range of vegetable species limited both by these extremes and by the length of the growing season, it follows that an age of great land extent must, through its fossils, give evidence of an excessive zonal climatic contrast, or appear in middle and higher latitudes to have been one of harsh climates, while an age of small land extent, even though the world as a whole had the same average temperature as before, must similarly record a much less zonal contrast and a spread of genial climates to far higher latitudes.

In the above attention has been confined strictly to land surfaces, their elevation and their areas, but continental mountain ranges and plateaus are not the only portions of the earth subject to changes in elevation and extent. Ocean beds and submarine ridges must also vary in both particulars, and, in turn, profoundly modify both local temperatures and zonal contrasts. Some of these ridges doubtless have alternately risen quite to the surface, perhaps at times much higher, and again sunk to considerable depths, and in each case inevitably have produced greater or less climatic changes through the resulting alterations in the oceanic and atmospheric circulations, and, perhaps, in other ways.

12, 13. ATMOSPHERIC AND OCEANIC CIRCULATION.

As everyone knows, practically the entire amount of heat that maintains the surface temperature of the earth is the result of the absorption of solar energy, chiefly by the lower atmosphere and by the various superficial coverings of the surface—vegetation, soil, rock, and water. On the average, the daily supply of this heat per unit area is much greater within the Tropics than it is at higher latitudes, a condition that maintains two distinct, though largely interdependent, systems of perpetual circulation, the atmospheric and the oceanic, that tend to equalize the temperatures of the earth—that keep the tropical regions from becoming unbearably hot and the frigid zones from being unendurably cold.

Clearly, then, any modification of either of these circulations would produce a corresponding change of climates, and the cause of this modification might properly be regarded as the cause of the given climatic changes themselves. But preliminary to a consideration of the probable climatic effects of any such modification it will be necessary, first, briefly to examine both circulations as they now exist.

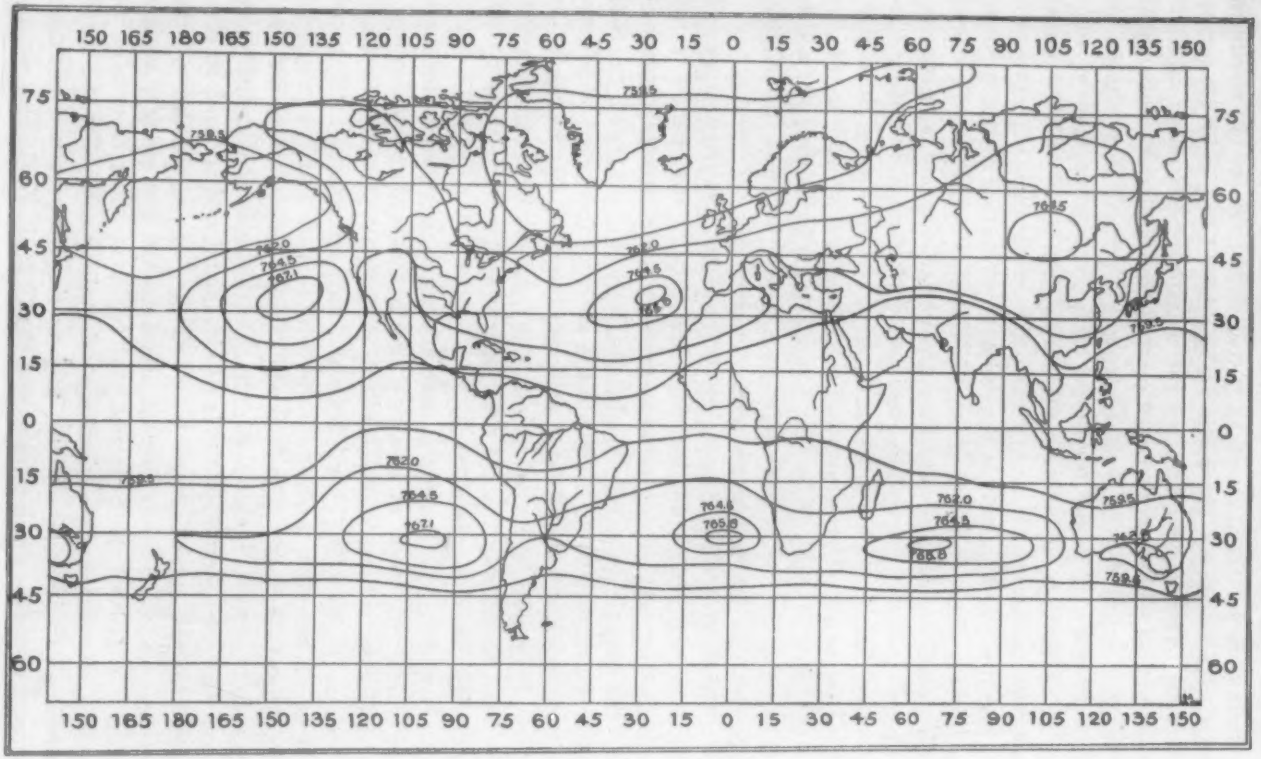
Present Atmospheric and Oceanic Circulations.—Despite innumerable disturbances, great and small, the fundamental circulation of the atmosphere is from equatorial toward polar regions and return, over a surface that moves from west to east with a linear velocity that gradually decreases with increase of latitude. As a result of these conditions the prevailing winds of latitudes higher than 32°, roughly, N. and S., blow from the west towards the east, or, to be exact, have a west-to-east component, while the winds between these latitudes, in the neighborhood, therefore, of the equator and the tropics, commonly blow, in the same general sense as above, from the east towards the west.

Now, the rotation of the earth has forced it to take the shape of an oblate spheroid—has bulged it at the equator and flattened it at the poles—and this distortion from the perfect sphere is such that an object on the surface is in equilibrium, so far as moving north or south is concerned, only when it has the same angular velocity about the axis of the earth that the earth itself has, or, in short, when it has no motion over the surface east or west. Obviously, then, an object moving from west to east, or with an angular velocity exceeding that of the earth, would be in equilibrium on a bulge greater than that which actually exists, and hence all winds with an eastward component, and, therefore, as stated, the prevailing winds outside latitudes 32° N. and S., must tend to climb up towards the equator. On the other hand, an object moving from east to west, or with an angular velocity less than that of the earth, as do the prevailing winds between latitudes 32° N. and S., must tend to slide down towards the adjacent or nearest pole. These opposite drifts of the winds, therefore, the drift of the winds of high latitudes toward the equator and the drift of the tropical winds toward the adjacent pole, obviously have produced the two belts of relatively high barometric pressure that roughly parallel the equator, the one at about latitude 32° N.; the other at approximately latitude 32° S.

Each belt of high pressure is greatly disturbed where it crosses a continental area, owing chiefly to temperature inequalities, but it also happens that even on the oceans the belts are of unequal intensity, and, what is of especial importance, have relatively fixed absolute pressure maxima or anticyclonic centres.

These permanent or nearly permanent centres of high pressure, or centres of action as they have been called, are five in

FIG. 7.



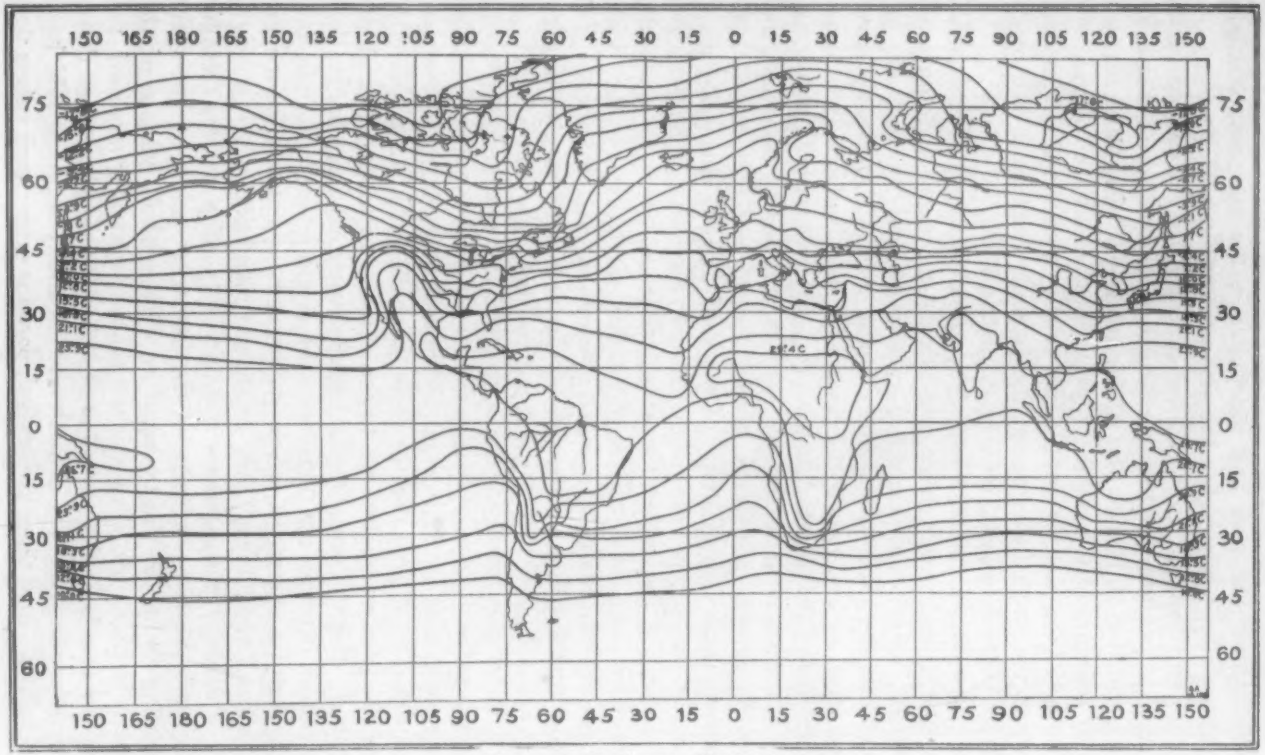
Mean annual isobars. (Buchan.)

number, as a reference to Fig. 7 will show; two in the northern hemisphere, one off the coast of southern California, the other near the Azores; and three in the southern hemisphere, one off the coast of Chile, another just west of South Africa, and a third between South Africa and Australia. Further, as is shown by Fig. 8, there is, in the region of each of these permanent anticyclonic centres, a marked equatorial deflection of the annual average isotherms, showing clearly that while each high pressure belt as a whole is caused by the mechanical squeeze of the opposite air drifts, above explained, the additional pressure that produces each maximum is a result of the local relatively low temperature, which causes a corresponding contraction and, therefore, increased density of the local atmosphere. And, finally, these particular low air temperatures in turn are caused by cold ocean currents, as is obvious from Fig. 9, and again from Fig. 10, which show the interrelations here considered between barometric pressure, air isotherms, and ocean currents.

That both the mere existence of these anticyclonic centres and their several geographic locations are of great importance to the climates of neighboring regions, through their directing influence on the prevailing winds, is obvious from Figs. 11 and 12, that give the directions and indicate the average force and steadiness of ocean winds at different seasons. But all this influence on the winds, however vital to many a local climate, can properly be said to be only one of the important climatic effects of the existing ocean currents.

In addition to the several permanent anticyclonic centres there are, also (see Figs. 11 and 12), one permanent cyclonic centre, the Icelandic "low," and one semi-permanent or winter cyclonic centre, the Aleutian "low," both of which are strongly influenced by ocean currents, the first by the Gulf Stream and the second by the Japan Current. The Icelandic "low" results from the temperature contrast between the air over the relatively warm water and that over the glacial fields of Greenland and Iceland, in consequence of which there is established a circulation in the sense of an overflow from the warm region and counter underflows from both the adjacent cold regions. This thermally induced circulation in conjunction with the rotation of the earth produces cyclonic conditions, and as the temperature contrasts are permanent (the Icelandic and the Greenland glaciers remain

FIG. 8.



Mean annual isotherms. (Buchan.)

throughout the year and indefinitely), the cyclonic conditions themselves of this region are also permanent.

The Aleutian "low," on the contrary, that is flanked by the Alaskan peninsula and the peninsulas of northeastern Siberia, has a circulation similar to that of the Icelandic "low," and for similar reasons, only while the adjacent land areas are covered with ice and snow and, therefore, are relatively cold. In the spring, when the snow melts away, the cyclonic conditions also disappear, there then being nothing to sustain them.

But the formation and geographic location of the above cyclonic and anticyclonic conditions—direction and force of winds, nature and frequency of storms, and the like—do not exhaust the more important climatic effects of existing ocean currents, as a glance at the annual average isotherms and ocean currents of the North Atlantic (Fig. 10) will show. In fact, the January isotherm of Chicago, Buffalo, and Boston (very approximately on the latitude of Rome), though not particularly cold, passes, under the influence of the Gulf Stream, through Iceland and on well beyond the Arctic Circle to the north of Norway and Sweden; while, under the same influence, frost is practically unknown and semitropical vegetation flourishes on the Scilly Isles in the latitude of northern Newfoundland. Similarly, it is said that because of the Japan Current frost rarely, if ever, occurs on one or two of the Aleutian islands.

Obviously, then, as the above several examples show, the ocean currents, driven by the winds, deflected by the rotation of the earth and by continental and island barriers, and otherwise modified by various minor causes, are both directly and indirectly of the greatest importance to the climates of many parts of the world; directly through the immense thermal interchange they establish between the torrid and the frigid zones, and indirectly through the centres of action, the permanent and semi-permanent "highs" and "lows," they create and maintain.

Possible Changes in the Oceanic Circulation and the Obvious Climatic Results.—Clearly, if the immense system of hot-water heating by which the temperature of the whole surface of the earth tends to become equalized should be greatly modified, say by the opening of a valve here or the closing of another there, correspondingly great climatic modifications surely would have to follow. And there are several, perhaps many, such valves that

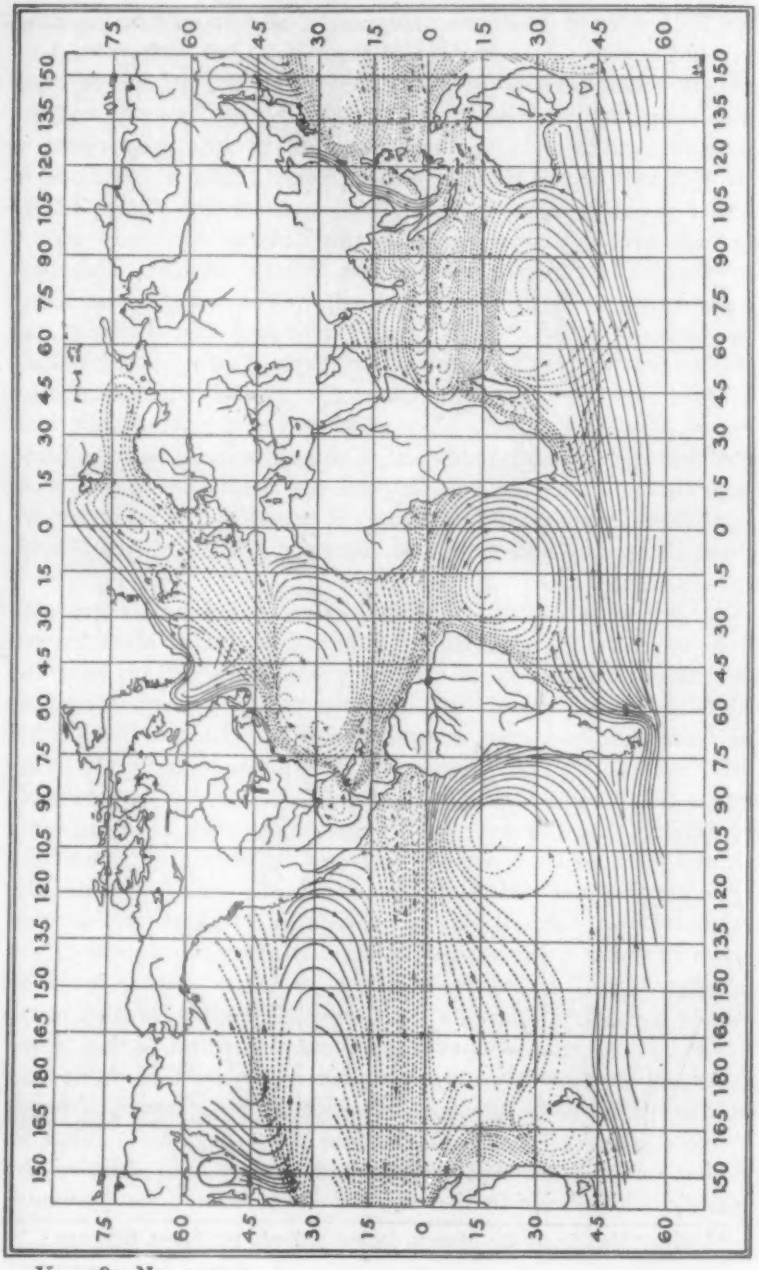


FIG. 9.

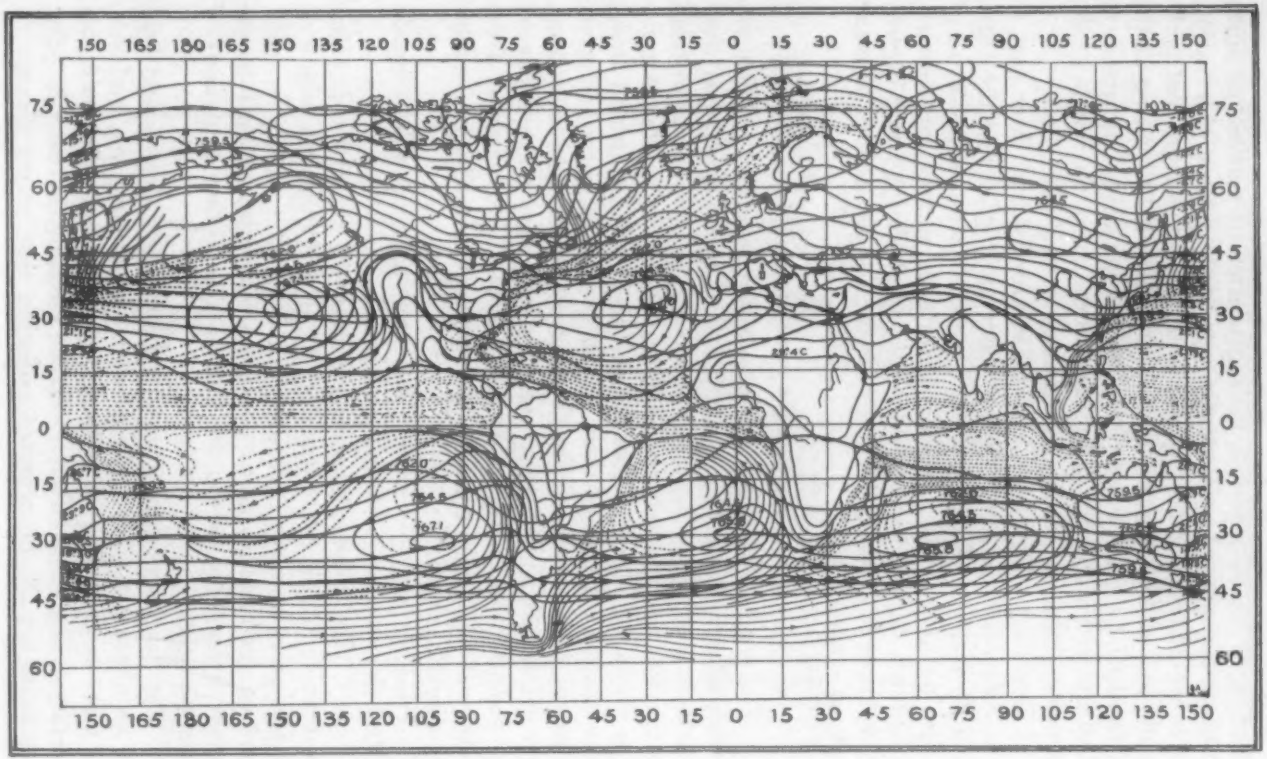
Ocean currents; full lines, cold; dotted lines, warm.

have been opened or closed, irregularly, and from time to time, since the beginning of geological records. One such valve now partially open, perhaps at one time closed and at another still wider open than at present, lies between South America and the Antarctic continent. Another, now but a little way open, is Bering Strait, which doubtless has greatly changed from one to another geologic age. Still another, now wholly closed, but at one time probably wide open, is the Central American region between the Caribbean Sea and the Pacific Ocean. This particular valve, if now widely opened, would, on the one hand, obliterate the Gulf Stream proper and probably diminish the Antilles current, and, on the other, greatly increase the Japan Current; and, of course, in each case induce widespread and marked climatic changes. Yet another valve, now rather wide open, that merits special mention, a valve that may have suffered many changes and have undergone its latest opening only in recent times, geologically speaking, is found in that ridge which by way of Iceland and the Faroe Islands connects Greenland with north Scotland.

With this Greenland-Scotland valve closed and even with all the other valves, channels of flow and deflecting obstructions, substantially as they now are, it is well-nigh certain that the Icelandic "low" would shift to some point between Greenland and Newfoundland; that Labrador and the Hudson Bay region would receive a greatly increased precipitation; that the Norwegian Sea would become largely, if not wholly, ice-covered; and, finally, that Norway and Sweden, since they have the same latitude as Greenland, would be swept by winds of practically Arctic temperature and, therefore, eventually would become, like Greenland itself, almost wholly ice-capped. Indeed, any decided change in either the average intensity or average position of the Icelandic "low," if continued for even a few weeks, seems to produce a marked influence on the weather of west and north Europe. In general, whenever the average position of this "low" during a winter month is considerably to the west of its normal place, as occasionally happens, the average temperature of north Europe is likely to be several degrees below normal.[53] That is, the above conclusion that a permanent or age-long shift of the Icelandic "low" far to the west of its present position would

[53] Hann, "Handbuch der Meteorologie," 3rd ed., pp. 632–3, 637, 639.

FIG. 10.



Superposition of ocean currents on mean annual isotherms and isobars.

lead to, or, at least, permit, the reglaciation of portions of north Europe appears to be abundantly supported by direct observation. Nor would these be all the profound climatic changes that probably, indeed well-nigh certainly, would follow the closing of the Greenland-Scotland valve, but they are sufficient, if granted, to indicate how vitally important the direction and magnitude of the ocean currents are to our climates and to local glaciation.

Doubtless many other valves have contributed their part in the control of the earth's great water circulation and the regulation of its climatic details, but it would be tedious to take all of them up individually, and for the present purpose unnecessary, since it is desired here only to make clear the fact that oceanic circulation is a vital factor in the production and control of many a local climate.

14. SURFACE COVERING.

The contrast between land and water in respect to their climatic effects obviously is largely due to the inequality of their surfaces both as radiators and as absorbers. The values of these properties are approximately known for the ocean, but not for the continents. In fact, there are no fixed values for land areas; nor can there be, since their surfaces undergo many and great changes. Bare soil, luxuriant vegetation, and snow, for instance, are among the surface coverings that have very unequal powers of radiation and absorption; and, therefore, the changes from one to the other over any extensive area necessarily is a matter of climatic importance.

To illustrate an extreme, but seemingly possible, climatic effect due to change of surface, assume:

(1) That continental areas are unusually extensive; (2) that mountains are abundant and high; (3) that during a period of a few years volcanic explosions are frequent (one a year, say) and of such nature as to put large quantities of dust in the upper atmosphere, as did the Krakatoa and other explosions of historic times.

The low temperatures due to the volcanic dust would lead to an abnormal extent of continental snow covering, and this, in turn, by its power of reflection, would render the insolation correspondingly less effective—would virtually decrease the solar constant, for all the reflected radiation that passes directly to

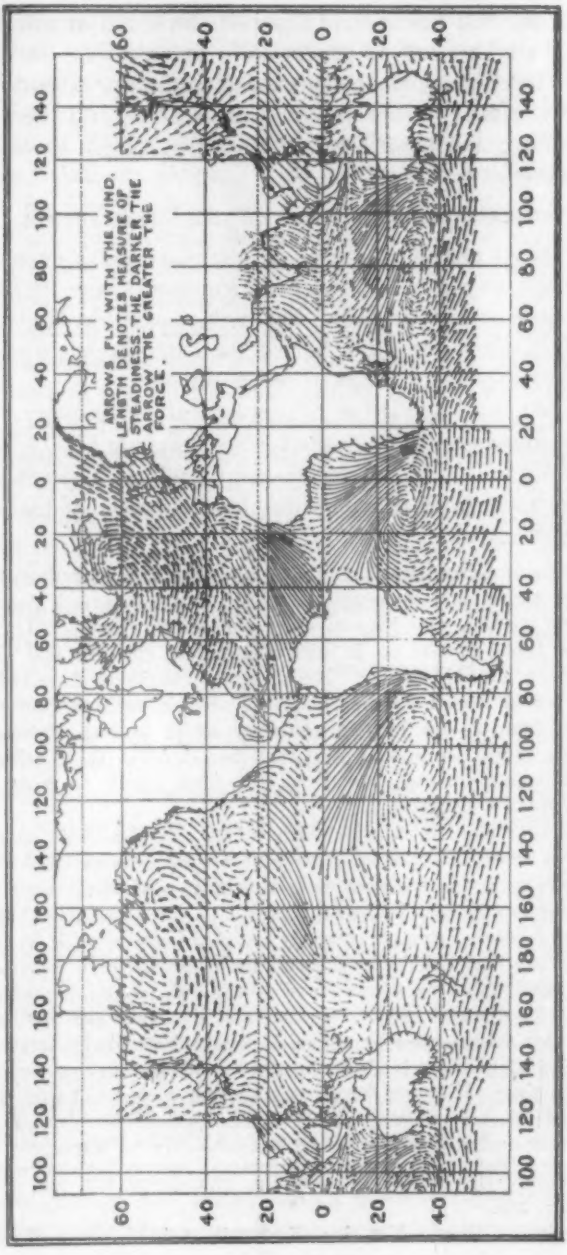

ARROWS FLY WITH THE WIND.
LENGTH DENOTES MEASURE OF STEADINESS. THE DARKER THE ARROW THE GREATER THE FORCE.
100 120 140 160 180 160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160 180 160 140 120 100
60 40 20 0 20 40

FIG. 11.

Normal wind direction and velocity, January and February. (Köppen.)

space had as well never have reached the earth at all, so far as producing any heating is concerned. In this way an ice covering of the land areas, far more extensive than previously existed, might be initiated by the volcanic explosions, and then perpetuated over long periods, if not even added to, by the highly reflecting snow cover.

CHRONOLOGICAL RELATION OF GEOLOGICAL EVENTS.

It is rarely possible to state in terms of years even approximately when any prehistoric geological event occurred or, similarly, to measure its duration, but it is possible in large measure accurately to decipher the order of their occurrence and to learn their chronological relations to each other.

Our present knowledge of geological chronology has been summarized by several geologists—Schuchert in his "Climates of Geologic Time," [54] for instance—all of whom, though differing in details, have much in common. In the course of his summary Schuchert [55] says:

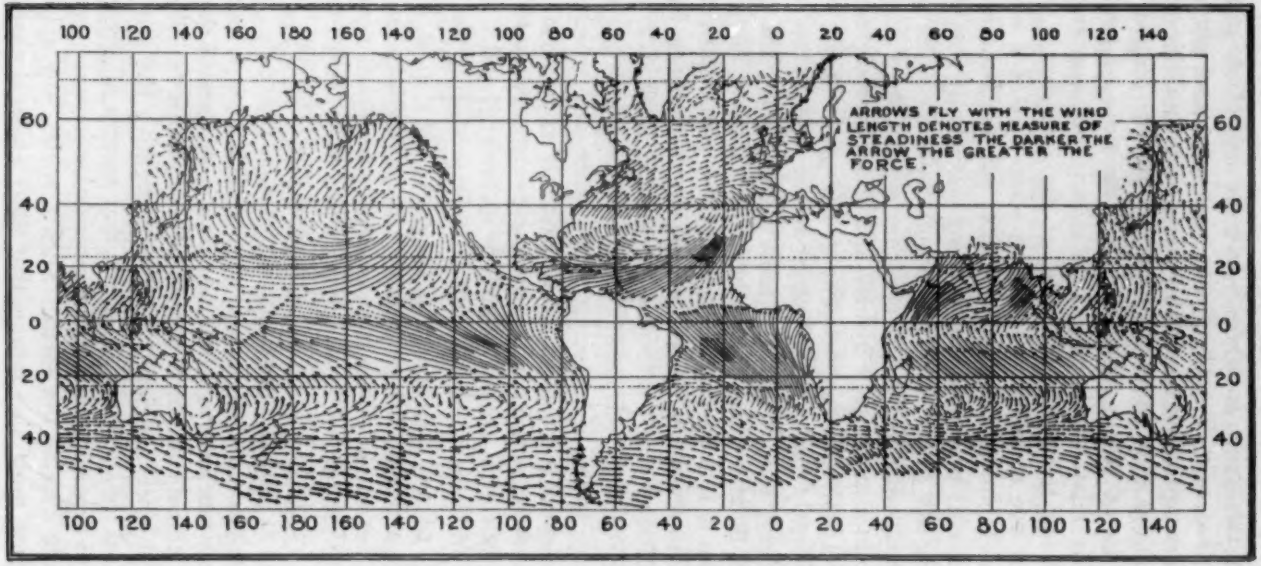
> The data at hand show that the earth since the beginning of geologic history has periodically undergone more or less widespread glaciation, and that the cold climates have been of short geologic duration. So far as known, there were seven periods of decided temperature changes, and of these at least four were glacial climates. The greatest intensity of these reduced temperatures varied between the hemispheres, for in earliest Proterozoic and Pleistocene time it lay in the northern, while in late Proterozoic and Permic time it was more equatorial than boreal. The three other probable periods of cooled climates are as yet too little known to make out their centres of greatest intensity.
>
> Of the four more or less well-determined glacial periods, at least three (the earliest Proterozoic, Permic, and Pleistocene) occurred during or directly after times of intensive mountain-making, while the fourth (late Proterozoic) apparently also followed a period of elevation. The Table Mountain tillites of South Africa, if correctly correlated, fall in with the time of the making of the great Caledonian Mountains in the northern hemisphere. On the other hand, the very marked and world-wide mountain-making period, with decided volcanic activity, during late Mesozoic and earliest Eocene times, was not accompanied by a glacial climate, but only a cooled one. The cooled period of the Liassic also followed a mountain-making period, that of late Triassic time. We may therefore state that cooled and cold climates, as a rule, occur during or immediately follow periods of marked mountain-making—a conclusion also arrived at independently by Ramsay.[56]

[54] Carnegie Institution of Washington, Publication No. 192, p. 285, 1914.
[55] *L. C.*, p. 286.
[56] Oversigt af Finska Vet.-Soc. Forhandl., vol. lii, pp. 1–48, 1910.

From the above, with which most geologists are in accord, it appears that neither cold climates nor even cool climates ever occurred except when mountains were either building or at least geologically young, and, also, so far as may be judged from the Strand line of North America, when the ratio of land area to ocean was relatively large. This coincidence appears to have occurred too frequently to admit of the idea that it was mere chance or due to anything less than some sort of a casual relation—surely not that the cold climates produced the mountains, nor necessarily that mountain building was wholly responsible for glaciation, but rather that crustal uplift and the other geological phenomena, whatever they were, that went with it so combined as to produce at one time a small and at another a great climatic change. If, also, as supported by geological evidence, vulcanism (only violently explosive volcanoes are of especial climatological importance), was, in general, most active during the epochs of mountain building, but unequally so for different mountain systems, then it follows that at each of these particular times there obtained to a greater or less degree precisely those formations and conditions—high mountains, extensive land area, restricted oceanic circulation and much volcanic dust—which are known to be effective to-day in reducing temperature, and which, presumably, are entirely sufficient, when properly coöperating, to produce not only a cool climate, such as, relatively speaking, now prevails, but even climates that are severely glacial. Which of these several causes was most effective in producing the low temperatures of any given age in the past (they must have been unequally active at different epochs) it may be impossible to determine, but the brief duration of distinctly glacial ages in comparison to the much longer periods when mild climates prevailed seems strongly to favor the assumption that vigorous vulcanism was often at least an important contributing factor.

But whatever else geologic chronology, as it is now understood, may teach in regard to the climatic changes of the past, the practical coincidence of cold ages with mountain building epochs appears at once and irretrievably to negative the entire group of cosmical ice-age theories—those that assume all great climatic changes to depend upon the sun, a condition in space, or anything else wholly outside the earth. Such theories, any solar theory, for instance, must also assume that those external changes, solar

FIG. 12.



Normal wind direction and velocity, July and August. (Köppen.)

changes, say, which caused a marked lowering of terrestrial temperatures, occurred only at or about the times of mountain building. That is, they must assume that either (*a*) the solar changes caused the mountain building, or (*b*) that mountain building caused the solar changes, or, finally (*c*) that both had some unknown but simultaneously acting common cause. But each of these assumptions is wholly untenable—it has no support whatever in the logic of cause and effect—and, therefore, it seems that any theory that implicitly or otherwise is definitely hung on the horns of this dilemma, as is every cosmical ice-age theory, nebular, or what not, must itself be abandoned.

This is not intended in the least to deny or even to question the existence of small solar changes of comparatively short duration, but only to emphasize the fact that phenomena within the earth itself suffice to modify its own climate, and that there is much and accumulating evidence that these and these alone have actually caused great changes time and again in the geologic past: done so by building mountains, and by tearing them down; by emerging continents, and by submerging them; by restricting ocean currents, and by making wide their paths—actions no doubt frequently accompanied by atmospheres at times heavily charged with the dust from violent volcanic activity and at other times cleared of foreign substances.

CONCLUSION.

It appears from various considerations that, with a constant or nearly constant output of solar energy, the earth itself possesses the inherent ability to profoundly modify its own climates, whether only local or world-wide. Thus, a mere change in land elevation, whether of plateau or of mountain range, a thing that appears often to have happened, must alter both the local and the leeward climates, and, by reducing the general humidity, somewhat lower the average temperature. Besides, a change in land elevation of any considerable extent is pretty certain to be accompanied by a somewhat corresponding variation in continental area, and such modification of shore lines and ocean beds that greater or less changes must follow in the directions, temperatures, and magnitudes of ocean currents, in the location and intensity of permanent "highs" and permanent "lows," in the direction, force and temperature of local winds, in the amount

and kind of local precipitation, and in a host of other meteorological phenomena.

Again, as the laws of radiation indicate must be true, and as observations, at least back to 1750, the date of the earliest reliable records, show, the temperature of the lower atmosphere depends in part upon the amount of dust in the upper air, in the sense that when this amount is great the average temperature at the surface of the earth is below normal, and when the dust is absent this temperature is comparatively high. Hence, as there appear to have been several periods of great volcanic activity in the past with intervening periods of volcanic quiescence, it is inferred that volcanic dust in the upper atmosphere was at least one important factor in some, if not all, of the great and universal climatic changes that have left their records in abandoned beaches and forsaken moraines.

How these various causes of climatic changes were related to each other during the geologic past is not yet entirely clear. This the geologist, most interested and most competent to judge, must determine. May it be that extensive upheavals and great volcanic activity often were synchronous? If so, the climatic effects of each obviously were added to those of the other, and hence it may be that the greatest of our past climatic changes were caused by the roughly synchronous variations in continental level and volcanic activity; universal cold periods coming with increase in vulcanism, increase in elevation and the obstruction of interzonal oceanic circulation; universal mild periods when volcanic dust seldom veiled the skies, when the continents had sunk or been eroded to low levels and when there was great freedom of oceanic circulation from equatorial to polar regions; mild universal climatic oscillations with temporary changes in vulcanism; and mere local climatic changes with variations in such local climatic controls as near-by elevations and neighboring ocean currents. Finally, as the past is the pledge of the future, it is but reasonable to suppose that the world is yet to know many another climatic change, in an irregular but well-nigh endless series, often local and usually slight, though always important, but occasionally, it may be, as in the ages gone—whether towards the auspiciously genial or into the fatefully disastrous—universal, profound and momentous.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ANNUAL REPORT OF THE DIRECTOR OF THE BUREAU OF STANDARDS.[1]

[ABSTRACT.]

A REVIEW of the work of the National Bureau of Standards for the year ended June 30, 1919, is given in the Annual Report of the Director of the Bureau of Standards at Washington. The report describes the functions of the Bureau in connection with standards and standardization, and contains a chart and description of the several classes of standards dealt with. The Director also gives a clear idea of the relation of the Bureau's work to the general public, to the industries, and to the Government, and includes a special statement of the military work of the year. Brief statements are made upon practically all of the special researches and lines of testing completed or under way at the Bureau. The list of these topics occupies 12 pages in the table of contents.

The Bureau is organized in 64 scientific and technical sections and 20 clerical, construction, and operative sections. During the year the Bureau has issued 51 publications, not including reprintings, 36 of which were new and 15 revisions of previous publications. In the several laboratories of the Bureau more than 131,000 tests were made during the year. The appropriations for the year, including special funds for war investigations, were approximately $3,000,000. A noteworthy event of the year included the completion of the industrial laboratory in which will be housed the divisions having to do with researches and tests of structural materials. The building also includes a commodious kiln house for use, among other purposes, of the ceramics division in the experimental production of new clay products and for general experimental purposes.

The report comprises 293 pages and may be obtained as long as free copies are available by addressing the Bureau of Standards, Washington, D. C.

* Communicated by the Director.

[1] Miscellaneous Publication No. 40.

SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF RAILROAD TRACK SCALES.[1]

[ABSTRACT.]

THE active coöperation between the Bureau of Standards, the Railroad Administration, the State of Minnesota, the American Railroad Association, the American Railway Engineering Association, the Scale Manufacturers' Association, and the National Scale Men's Association, has resulted in new standard specifications for railroad track scales which are satisfactory to all concerned.

The private purchaser is now in a position to secure authoritative information on what he should buy and is enabled to know what he is getting. Adequate standardized scales for all ordinary purposes should, therefore, replace the needless multiplicity of designs, many of which were inadequate.

The subject has been handled from a national viewpoint. This was somewhat difficult as conditions vary widely throughout the country, but the value of the completed work is correspondingly greater. What is of particular importance, all interests have for the first time agreed on very complete and detailed standard specifications for track scales which are satisfactory to all concerned. These specifications will, therefore, form the basis for standardizing railroad track scales for ordinary weighing requirements.

The provisions have been drawn to secure the economy of standardized construction without the detrimental features sometimes associated with over-standardization. The general adoption of these specifications should greatly promote the use of proper scales and weighing facilities and at a minimum cost. This will aid railroads, private owners, industries, and the Federal and State governments which have concerned themselves with this important subject. The weighing of carload freight on American railroads can thus be greatly improved and brought to a high standard of practical efficiency.

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[1] Circular No. 83

THE PROPERTIES OF AMERICAN BOND CLAYS AND THEIR USE IN GRAPHITE CRUCIBLES AND GLASS POTS.[3]

By A. V. Bleininger.

[ABSTRACT.]

THE properties of American bond clays are described in detail and expressed through characteristic numerical values with special reference to their burning behavior. It is shown that materials equal in quality to those formerly imported from Germany are available and that by suitable blending any desired combination of properties can be readily produced. The characteristics of natural and artificial graphite are described and means suggested for the control of crucible mixtures. The fact is brought out that the main advantage in the use of German glass pot clay consists in its low fire shrinkage and suggestions are made for obtaining similar conditions with the use of domestic materials and with increased resistance to corrosion. The compositions and the preparation of semi-porcelain and porcelain glass pots are given. The method of casting glass pots as practiced at the Pittsburgh laboratory of the Bureau of Standards is also described.

RECOMMENDED SPECIFICATION FOR BASIC CARBONATE.[4]

[ABSTRACT.]

THIS specification was prepared and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, August 11, 1919. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of this specification to a number of representatives of the paint and varnish industry, including all of the large manufacturers of white lead, and gave careful consideration to the replies received in time.

This specification gives chemical and physical requirements for dry basic carbonate white lead and basic carbonate white lead ground to a paste in linseed oil. Methods of sampling and methods of testing both dry pigment and paste are made part of the specification. For details the original should be consulted.

[3] Technical Paper 144.

[4] Circular No. 84.

Relative Contribution of the Staple Commodities to the National Food Consumption. RAYMOND PEARL. (*Proceedings of the American Philosophical Society*, 1919, lviii, 182–222.)—Over one-half of the *protein* eaten by the American people is contained in animal foods other than fish; 36 per cent. of the protein ingested is normally derived from grains (including 28 per cent. from wheat), 26 per cent. from meats, 20 per cent. from dairy products, and approximately 7 per cent. from poultry and eggs. Of the *fat* eaten, 51 per cent. is furnished by meats (including 40 per cent. supplied by pork and its products), 27 per cent. by dairy products, 12 per cent. by oils and nuts. Of the *carbohydrate* eaten, 56 per cent. is derived from grains, 26 per cent. is taken as sugars; vegetables, fruits, and dairy products contribute smaller per cents to the total. Grains supply 35 per cent. of the *energy* (calories) in the nation's diet, meats 22 per cent., dairy products 15 per cent., sugars 13 per cent., vegetables 5 per cent., fruits 2 per cent., poultry 2 per cent., vegetable oils and nuts 5 per cent. The average daily food consumption by an adult man is 114 grammes protein, 127 grammes fat, and 433 grammes carbohydrate; this gives an average daily consumption of 3424 calories.

J. S. H.

Application of Sanitary Science to the Great War in the Zone of the Army. BAILEY K. ASHFORD. (*Proceedings of the American Philosophical Society*, 1919, lviii, 317–336.)—Sanitary science has reduced the number of deaths from disease in the army during war-time. The number of deaths per 1000 of strength annually was: Civil War, 65; Spanish-American War, 30; Great War, 14.8, including 12 due to epidemic pneumonia. Protective vaccination against typhoid and its congeners was so efficient that but 17 cases of typhoid and 10 cases of para-typhoid developed in the First American Army of 1,000,000 men up to January 1, 1919. Administration of a protective dose of tetanus antitoxin to all the wounded reduced the percentage of cases of tetanus (lock-jaw) in the wounded from 3.2 per cent. in 1914 to a small fraction of 1 per cent. in 1917. In the trenches and the field, treatment of the water in a Lyster bag with hypochlorite was used to obtain a safe supply of drinking water. In open warfare, sanitation was reduced to a mere shred. Soakage pits were used for disposal of the urine. Latrines were rendered fly-proof. In the trenches latrines for feces were located in blind off-shoots from communicating trenches; they were either deep pits or else provided with buckets which were emptied, with the garbage from the food, into adjacent shell holes at night. In the back area, the British used bucket latrines for feces; each bucket contained a small amount of cresol; twice a day 20 per cent. of saw-dust was added to each bucket which was then emptied into an incinerator.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE HYDROLYSIS OF STIZOLOBIN, THE GLOBULIN OF THE CHINESE VELVET BEAN, STIZOLOBIN NIVEUM.[1]

By D. Breese Jones and Carl O. Johns.

[ABSTRACT.]

STIZOLOBIN, the globulin of the Chinese velvet bean, was hydrolyzed and the resulting amino acids determined quantitatively. Glutaminic acid was isolated directly as the hydrochloride, and the remaining amino acids separated, for the greater part, by the usual ester method. A modification of the customary method for the determination of proline is described which does not involve the ester method. Aspartic, and hydroxy-glutaminic acids were determined in a separate hydrolysis according to the method of H. D. Dakin. A striking result of the use of this method is the extraordinarily high percentage of aspartic acid obtained, namely, 9.23 per cent., while only 5.70 per cent was obtained from the esters.

The following percentages of amino acids were obtained as a result of this hydrolysis. Glycine, 1.66; alanine, 2.41; valine, 2.88; leucine, 9.02; phenylalaine, 3.10; aspartic acid, 9.23; glutaminic acid, 14.59; hydroxy-glutaminic acid, 2.81; serine, 0.67; tyrosine, 6.24; cystine, 1.13; arginine, 7.14; histidine, 2.27; lysine; 8.51; ammonia, 1.55. The presence of tryptophane was shown.

PHTHALIC ANHYDRIDE. II. THE MELTING POINT OF PURE PHTHALIC ANHYDRIDE. THE SYSTEM: PHTHALIC ANHYDRIDE—PHTHALIC ACID.[2]

By K. P. Monroe.

[ABSTRACT.]

VERY pure phthalic anhydride was prepared by re-sublimation in vacuo in the presence of P_2O_5. The melting point was estab-

* Communicated by the Chief of the Bureau.

[1] Published in the *Journal of Biological Chemistry*, vol. xl, No. 2, December, 1919.

[2] Published in the *Journal of Industrial and Engineering Chemistry*, vol. xi, No. 12, December, 1919, p. 1116.

lished as 130.84°, while the eutectic temperature of phthalic anhydride and phthalic acid was determined to be 129.74°. The freezing point curves for the system, phthalic anhydride-phthalic acid, were explored over the somewhat limited region of the system to which the experimental method was applicable. By plotting reciprocals of absolute freezing points against logarithms of mole fractions of acid the melting point of pure phthalic acid, which can not be determined directly, was indicated to be 208 ± 2°.

PHTHALIC ANHYDRIDE. III. THE SYSTEM: NAPHTHALENE—PHTHALIC ANHYDRIDE.[1]

By K. P. Monroe.

[ABSTRACT.]

THE freezing point curves of this system were determined in an apparatus specially designed to obviate difficulties encountered in systems of substances which sublime readily at the melting point. Observed freezing points on one curve (naphthalene as solid phase) agreed closely with calculated values based upon the Schröder-Le Chatelier formula; the other curve (phthalic anhydride as solid phase) was tested by re-casting this formula so that the molar heat of fusion of phthalic anhydride could be calculated from the individual points. Satisfactory agreement was observed, indicating that this curve, as well as the former, conforms to the law of ideal systems. The molar heat of fusion so calculated was 5480 calories.

Damage to France During the War. ANON. (*Steam*, vol. xxiii, No. 3, p. 76, September, 1919.)—A hasty investigation since the signing of the armistice shows the total destruction in France of something like 500,000 buildings damaged and at least 250,000 building completely destroyed. This destruction of buildings is estimated at $6,000,000,000 by the Government engineers. The total cost of repairing and replacing the used or destroyed public works is estimated at about $2,000,000,000. The Nord railroad alone has lost 1731 bridges and 338 stations. It is estimated that 250,000 acres are rendered uncultivatable by the war. The total damage in the north of France, including, buildings, agriculture, industry, furniture and public works, is estimated at about $13,000,000,000.

R.

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[1] Published in the *Journal of Industrial and Engineering Chemistry*, vol. xi, No. 12 December, 1919, p. 1119.

NOTES FROM THE U. S. BUREAU OF MINES *

SENSITIVENESS OF EXPLOSIVES TO FRICTIONAL IMPACT.

By S. P. Howell.

MANY commercial explosives may be exploded by severe and prolonged friction, some being more sensitive than others in this regard. Explosives containing potassium chlorate are especially likely to explode under such conditions. Tests to determine sensitivity to frictional impact having previously been made by unsatisfactory equipment, a pendulum friction device, described in Technical Paper 234, Bureau of Mines, that permits uniformity of execution, was designed and built. The results of tests with this device on a large number of explosives and under varied conditions are given in the publication noted above. They indicate that the tests are not too severe, since potassium chlorate explosives which failed to pass the test exploded prematurely in commercial use; all explosives of this type being extremely sensitive to frictional impact. Those potassium chlorate explosives that passed the tests were rendered sufficiently insensitive to friction by adding an adequate quantity of mineral oil, vegetable oils, and aromatic nitro compounds, or by reducing the potassium chlorate to a small percentage. The sensitiveness of such explosives to friction is greatly increased by the presence of pyrite-bearing coal. Black blasting and ignition powders, blasting gelatin, ammonia dynamites, and organic nitrate explosives are not as sensitive to friction impact as the nitro-glycerin and gelatin dynamites.

APPROXIMATE QUANTITATIVE MICROSCOPY OF POWDERED ORES.

By Will H. Coghill and J. P. Bonardi.

IN ascertaining the physical and chemical properties of any given ore preparatory to prescribing the best method for its concentration, as many methods of gathering information as are feasible should be employed, so that all significant properties may be detected. Hynes, while working with one of the writers sev-

* Communicated by the Director.

eral years ago, developed a method of sorting under a reading glass, and applied it to sized grains as small as 28 mesh. In Technical Paper 211, Bureau of Mines, under the title given above, we show how to improve on Hynes' method by using an offset device which makes the counting of grains smaller than 28 mesh much less irksome. A binocular microscope is preferable to the monocular instrument used in the earlier methods. Close and thorough screen sizing is essential. The separate screen products must be washed and dried so as to present clean and bright mineral surfaces. A wetting solution that contains saponin or soap is best for wet screening of the finer sizes, and re-screening may be necessary to separate particles grouped by cohesion and adhesion. The finer products should be spread over the microscope plate by the use of a fine sieve. Orientation for each reading is made by adjusting the glass slide along a ruled offset. The advantages claimed for the method there described are its low cost, rapidity, that it gives a closer approximation to chemical analysis than is obtainable by the earlier methods, and serves as a guide to the metallurgist in mill operations. A typical record sheet is given, and the method is illustrated by applying it to the "grading up" of molybdenite concentrates, followed by an interpretation of the results and their application to this metallurgical problem.

ABATEMENT OF CORROSION IN CENTRAL HEATING SYSTEMS.

By F. N. Speller.

WHETHER hot water or steam is used as the medium for conveying heat to the consumer, a heavy toll in upkeep must be faced sooner or later if the corrosion of the piping has not been taken into account in the design of the plant. The main source of corrosion has been traced to dissolved gases brought into the system either with the feed water for the boiler or through leaks in the return lines under a pressure below that of the atmosphere. In a recent paper by F. N. Speller and R. G. Knowland (Preservation of hot water supply pipes in theory and practice, Proc. Am. Soc. Heat. and Vent. Eng., vol xxiv, 1918, pp. 217–240) an outline of the fundamental reactions of corrosion is given. It has been well established that the factors which cause corrosion rather than any commercial difference in the composition of the pipe, de-

termine the rate of corrosion, and a considerable number of service tests of the corrosion of pipe carrying hot water indicates practically no difference, on the whole, among reputable makers of wrought iron and steel pipe. Pipes for hot water heating do not suffer seriously if the same water is circulated repeatedly, but the corrosion becomes rapid if much make-up water is added, especially in districts where the water is soft. In systems using open heaters where the water was allowed to come to rest at 180° F., or higher, thus discharging the gases, the pipes showed practically no corrosion in 10 years' service. In another system a storage tank filled with expanded steel lathing was used, practically all the free oxygen was removed in the tank, and in three years there was practically no corrosion in the pipes. The free CO_2 present is not removed by this treatment, hence it was concluded that the effect of CO_2 in such a system is negligible. In a steam heating system any non-condensable gases in the feed water are reabsorbed by the condensate and may cause serious corrosion, especially along the bottom of horizontal lines. The gases may be removed from the feed water by the use of open heaters, especially if assisted by a steel sheet. Air leakage in steam returns should be avoided as much as possible. Where exhaust steam is used a coating of oil usually forms on the inside of return pipes and protects them. Corrosion of the blades of a steam turbine was halted by adding heavy paraffin base oil to the steam head of the turbine. Further details as to protecting piping from the harmful effects of free oxygen will be found in Technical Paper 236, U. S. Bureau of Mines.

SAFE PRACTICE IN USING WIRE ROPE IN MINES.

By R. H. Kudlich and O. P. Hood.

THE essentials of good practice in the use of wire ropes in mining and the reasons underlying it are given in Technical Paper 237, U. S. Bureau of Mines. The statements in this are so condensed that they cannot be abstracted. The topics discussed are size of rope, material, construction of rope, lay of rope, length of rope, sheaves and drums, position of drums, idler sheaves and rollers, handling and storage of ropes, attachment of rope, renewal of rope-fastenings, safety chains, attachment of ropes on slopes, lubrication of ropes, inspection of hoisting ropes, rules for discarding ropes.

DANGEROUS AND SAFE PRACTICES IN BITUMINOUS COAL MINES.

By Edward Steidle.

THE use of photographs to illustrate safe and unsafe practices in bituminous coal mines was chosen as the basis of Miner's Circular 22, of the U. S. Bureau of Mines. The photographs were made in coöperation with the Ellsworth Collieries Co., Ellsworth, Pa., and the Consolidation Coal Co., Fairmont, W. Va. Some of the photographs show more than one bad or good practice. The pictorial method is considered to be the most effective one in appealing to miners, especially those who find difficulty in the use of the English language. In 1907, out of every 1000 employes in coal mines in the United States, 4.81 were killed, while in 1916 3.03 were killed, showing the effect of the campaign for safety in the mining industry which has been carried on by the Bureau of Mines.

Concrete Parts for Generators. C. M. HACKETT. (*General Electric Review,* vol. xxii, No. 10, p. 843, November, 1919.)—With our present knowledge of aggregates, cement, water and the methods of combining them it is possible to get not only uniform strength in all parts of a concrete structure of large size and mass, but also to produce duplicates of that structure in any quantity desired. This progress, combined with the great strength of the finished product, has led to the adoption of reinforced concrete for various classes of work where metal heretofore has been regarded as the only suitable material.

There are two parts of large size, in low speed vertical shaft electric generators of hydro-electric installations, that with advantage can be made of reinforced concrete, namely, the stator frame and thrust-bearing support. The use of concrete instead of metal for these parts does not involve any problems of stability or strength that cannot readily be solved by care in design and construction. Some of the large alternating current generators require stator frame and bearing support-castings of enormous size that tax manufacturing and shipping facilities. The economies to be found in the substitution of concrete for metal in these parts lie chiefly in the lower cost of materials and labor, reduction in shop expenses, and savings in freight and handling charges. It appears also practicable to build stator frames of concrete for large size horizontal shaft machines, using either a solid or split ring, as may be desired.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, December 17, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 17, 1919.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to the membership since last report, 5.

Reports of progress were presented by the Committee on Library, and the Committee on Science and the Arts.

The following nominations were made for officers and managers to be voted for at the annual election to be held on January 21, 1920:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Coleman Sellers, Jr.; (to serve one year), Charles Day.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), Gellert Alleman, G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, George D. Rosengarten, Wm. Chattin Wetherill; (to serve one year), Howard S. Graham, C. C. Tutwiler. The following members were appointed to act as tellers of the election: Messrs. W. N. Jennings, Henry F. Colvin, and Lucien E. Picolet.

The President then announced that the Philadelphia Association of Members of the American Society of Civil Engineers was meeting jointly with the Institute, and requested Mr. S. M. Swaab, President, to take the chair.

Brigadier General R. C. Marshall, Jr., was prevented from attending the meeting because of serious illness in his family, and his paper on "The Construction Division of the Army" was read by Colonel G. R. Solomon, Chief of the Engineering Branch of the Construction Division, U. S. Army, War Department, Washington, D. C. An account was given of the work of providing camps and cantonments in the various parts of the country for the citizen soldiery called to the Colors soon after the entry of the United States into the World War. In addition to housing accommodations for more than two million men, the Construction Division built arsenals, storage depots, industrial plants, gas plants, proving grounds, etc., for the Ordnance Department; hospitals with a capacity of more than one hundred and twenty-one thousand beds for the Medical Department; huge storage depots and port terminals at several points along the Atlantic Coast for the Quartermaster Department; warehouses and flying fields for the Signal Corps; mechanical repair shops for the Motor Transport Corps; and embarkation and debarkation facilities for the Transportation Service. The water supply for the various camps presented a serious problem,

and it was necessary to install 275 different water supply systems, involving the construction of 1100 miles of pipe, from 6 to 30 inches in diameter; 700 miles of service pipe, ¾ to 2 inches in diameter, with a combined pumping capacity of 650,000,000 gallons per day; filter plants were built having a capacity of 40,000,000 gallons. The construction projects undertaken for the Ordnance Department, embracing many new problems of construction and manufacture, plant layouts and shop arrangements were also described. There were 60 of these projects, costing a total of $175,000,000. The subject was illustrated by lantern slides, photographs, diagrams, plans and drawings, many of these being loaned by Lieutenant Colonel E. B. Morden, U. S. A., the Constructing Quartermaster, at Philadelphia, the officer in charge of the construction of the U. S. Army Supply Base at Greenwich Point, Philadelphia. A discussion followed the reading of the paper, in which Lieutenant Colonel Morden, Mr. Henderson, Mr. Penrose, and others participated. On the motion of Mr. Henderson, duly seconded, it was directed that the meeting express its regrets at the absence of General Marshall, and that its thanks be extended to Colonel Solomon.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 3, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 3, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for final action:

No. 2713: Kemp Gas System. Edward Longstreth Medal of Merit awarded jointly to William Wallace Kemp and William H. Van Horn, both of Baltimore, Maryland.

The following reports were presented for first reading:

No. 2731: Hydrogenation of Oils.

No. 2740: Barker Wrenchless Chuck.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, November 13, 1919, at 8 o'clock. Mr. Samuel S. Sadtler, on behalf of the American Chemical Society, and Dr. Joseph S. Hepburn, on behalf of the Institute, presided jointly. The minutes of the previous meeting were approved.

E. V. McCollum, Ph.D., Professor of Bio-Chemistry in the School of Hygiene and Public Health of The Johns Hopkins University, Baltimore,

Md., delivered a lecture on "Nutrition and Physical Efficiency." A résumé was given of researches in nutrition conducted on animals during the past decade, with special reference to the etiology and correction of "deficiency diseases." The dietary habits of the lower animals and man in various geographical regions were reviewed in the light of this newer knowledge; and deductions were drawn concerning those diets which are most satisfactory for the promotion of physical vigor.

The paper was discussed; a rising vote of thanks was extended to Dr. McCollum, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, December 4, 1919, at 8 o'clock. Mr. George R. Henderson in the chair. The paper of the evening on the "Destruction of French Coal Mines and Their Rehabilitation" was presented by Mr. George S. Rice, Chief Mining Engineer, Bureau of Mines, Department of the Interior, Washington, D. C.

It was shown that the destruction of the French coal mines in the Nord and Pas-de-Calais district was of two kinds, battle and systematic, systematic far exceeding the destruction incident to battle.

The collieries wrecked by the Germans produced, prior to the war, 20,000,000 tons of coal per annum. French engineers estimate that it will require five years, on an average, to place the mines on an operating basis and ten years to recover their normal output. The subject was illustrated by lantern slides from photographs taken by the lecturer, and from official photographs furnished by the French Government.

After a discussion of the paper by Messrs. Price, Penrose, the chairman and others, a vote of thanks was extended to the speaker, and the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held on Thursday evening, December 11th, at 8 o'clock, in the Hall of the Institute. Dr. Harry F. Keller in the chair. The minutes of the previous meeting were read and approved.

E. W. Dean, Ph.D., Petroleum Chemist, U. S. Bureau of Mines, Pittsburgh, Pa., delivered an illustrated lecture on "Motor Fuels." The manufacture of gasoline by straight distillation of crude oil, by the cracking process, and by recovery from natural gas was described. Statistics were given concerning the production, consumption, and marketing of gasoline. The modes of testing motor fuels and various substitutes for gasoline as a fuel were described.

The paper was discussed by Drs. Keller, Goodspeed and Dean, and Messrs. Tutwiler, Fulweiler and Hicks. On motion of Dr. Walter T. Taggart a vote of thanks was extended to Dr. Dean. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, December 10, 1919.)

RESIDENT.

DR. HIRAM S. LUKENS, Chemist, Harrison Laboratory, University of Pennsylvania, Thirty-fourth and Spruce Streets, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. JAMES D. LEE, in charge of Technical Publicity, Westinghouse Lamp Company, Bloomfield, New Jersey.

MR. W. I. OHMER, President, Recording and Computing Machines Co., Dayton, Ohio.

MR. LEWIS K. SILLCOX, Mechanical and Electrical Engineer, 169 Twenty-sixth Street, Milwaukee, Wisconsin.

DR. R. B. VON KLEINSMID, President, University of Arizona, Tucson, Arizona.

CHANGES OF ADDRESS.

MR. C. O. BILLOW, 416 West Grand Avenue, Chicago, Illinois.

DR. GEBHART BUMCKE, in care of National Oil Products Co., Essex and Front Streets, Harrison, New Jersey.

MR. JAMES H. DAWES, 3300 Arch Street, Philadelphia, Pennsylvania.

MR. J. M. DIVEN, Secretary, American Water Works Association, 153 West Seventy-first Street, New York City, New York.

MAJOR THOMAS H. GRIEST, 1631 Arch Street, Philadelphia, Pennsylvania.

MR. R. K. HONAMAN, Development and Research Department, American Telegraph & Telephone Company, 195 Broadway, New York City, New York.

MR. HUTTON KENNEDY, The Hero Manufacturing Co., Twenty-third and Westmoreland Streets, Philadelphia, Pennsylvania.

MR. WILFRED LEWIS, Rose Lane, Haverford, Pennsylvania.

MR. FRED J. MILLER, 319 West Ninety-fourth Street, New York City, New York.

MR. ALEX. E. REOCH, in care of The Radio Corporation of America, 233 Broadway, New York City, New York.

MR. F. W. SALMON, General Delivery, Mobile, Alabama.

MR. EDWARD A. STROUD, 508 South Forty-first Street, Philadelphia, Pennsylvania.

MR. PERCY WEDLAKE, 125 Atlantic Street, S.E., R.F.D. No. 8, Anacostia Station, Washington, District of Columbia.

MR. DAVID H. WILSON, JR., Wilson Welder and Metals Co., 2 Rector Street, New York City, New York.

NECROLOGY.

Mr. Hugh McCaffrey, 1711 North 4th Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

American Electrochemical Society.—Transactions. Vol. xxxiv. 1918.
BOWER, C. O.—Practical Shell Forging. 1919.
JACOBS, F. B.—Abrasives and Abrasive Wheels. 1919.
JOHNSON, D. W.—Shore Processes and Shoreline Development. 1919.
LANGSDORF, A. S.—Principles of Direct Current Machines. 1919.
LIVEING, G. D., and DEWAR, SIR J.—Collected Papers on Spectroscopy. 1915.
LUNGE, GEORGE.—Coal-tar and Ammonia. 3 vols. 1916.
MANLOVE, G. H.—Scrap Metals. 1918.
MARTIN, T. C., and COLES, S. L., ed.—Story of Electricity. Vol. i. 1919.
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TURNEAURE, F. E., and MAURER, E. R.—Principles of Reinforced Concrete Construction. 1919.

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American Continuous Retort Company, Catalogue, Ore Treatment. Denver, Colorado, no date. (From the Company.)
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American Wood-Preservers Association, Proceedings of the Fifteenth Annual Meeting, St. Louis, Missouri, 1919. (From the Association.)
Atkins, E. C. Company, Inc., Catalogue of Saws and Saw Tools. Indianapolis, Indiana, 1919. (From the Company.)
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BOOK NOTICES.

THE ANALYSIS OF MINERALS AND ORES OF THE RARER ELEMENTS. FOR ANALYTICAL CHEMISTS AND ADVANCED STUDENTS. By W. R. Schoeller, Ph.D., and A. R. Powell. 234 pages, contents and indexes, 8vo. London, Chas. Griffin & Co.; Philadelphia, J. B. Lippincott Co. $5.00.

Interpreting the term "rarer" in a somewhat wider sense than that used in older chemistry, this work gives a valuable summary of the processes for over two dozen metals, ranging from such comparatively common ones as lithium, molybdenum and platinum, to the very rare cerium associates, and indium, gallium and radium. The improvement of methods of detection and separation, and the systematic search for these less common elements has brought to light many sources formerly unsuspected, and the special properties of some of them have brought them from brief allusions in text-books and reference works to important products of the industrial world and research laboratory.

As the authors state, only the rarest elements are yet without practical use, some supposed to be of very restricted occurrence have been found widely distributed, while others again have been of late years obtainable from local deposits of considerable extent.

The text-book methods of detection and separation of these elements belong in many cases to the science of fifty years or more ago, but the process of research in the hands of specialists, and the invention of new methods of investigation have brought about great changes, and it is the purpose of this volume to present the present-day procedures for the entire series. The book is packed with interesting and valuable information, much of which is presented in a condensed tabular form. The special methods of research, *e.g.*, spectroscopic and electroscopic, are described in detail, and it is interesting to note that the electroscope advised for radium determinations is taken from bulletin 104 of the United States Bureau of Mines. The metric system is used throughout, and the more advanced nomenclature for salts, although, as might be expected in a work of British provenance, the final "e" is retained in such words as "chloride." The ordinary unit of weight is written "grm." and cubic centimetre is abbreviated to c.c., both of which forms are commendable. In looking over the procedures, many of which are very complex, the thought occurs to the reviewer that before long, the optical methods now

attracting so much attention in mineralogy and organic chemistry will soon be applied to the field covered by this work, and give chemists valuable new methods of detecting and distinguishing between otherwise closely allied elements. Under thorium no reference is made to mesothorium, the importance of which would seem to justify at least a brief notice. Praseodymium and neodymium receive very brief notice also.

The book is excellently printed on good paper and the text is clear and carefully proof-read.

HENRY LEFFMANN.

NOTIONS FONDAMENTALES DE CHIMIE ORGANIQUE. By Charles Moureu, member of the Institute. Sixth edition, 552 pages, index and prefaces, 8vo. Paris, Gauthier-Villars, 1919. Price, 24 francs, net.

A previous edition of this work was reviewed in this journal a few years ago, but the present issue is larger by nearly fifty per cent. It is wholly a treatise on fundamental theories of the structure of organic bodies, practically no descriptive matter being given. A very large amount of information is furnished, and all the important theories are vividly and concisely presented. The printing and paper are of good quality; the type, though small, is easily read. The vast field of organic chemistry has been culled with judgment so as to compress within a convenient volume an introduction to the present-day theories that will be a guide to students and teachers. For the author's zeal and industry high praise must be given, but some features of the book require animadversion. The continued use by French chemists of the superiors instead of inferiors for the exponents in formulas has now no justification, and leads the reviewer to a suspicion that, as straws show which way the wind blows, some of the exceptional methods of French chemists indicate that if ever there is a league of nations, France will be a rather cantankerous member thereof. The equals sign is used always for reactions, instead of the arrow now generally preferred by chemists. The most serious of the infractions of the international rules is in the writing of the structural formulas of the cyclic compounds. The benzene hexagon is always written by our author with CH groups attached to the angles. Now Kekulé stated (*Ann. Chem. Pharm.*, 1866, v. cxxxvii, p. 129) that the plain hexagon stands for the whole molecule, C_6H_6, of benzene. This plan has been adopted by all careful writers in the field, and it is to be regretted that so excellent a work is marred by such a departure from a reasonable custom. Notice should also be made of such terms as "cétone" and "cétose." There seems to the reviewer to be no good reason for not using "k" as the initial in these words, for, though the letter itself is not an inherent member of the French alphabet, its sound is very frequent in the language and no person sufficiently educated to use this book can be unacquainted with the symbol and its pronunciation.

The work is very easy reading, very comprehensive and, in its presentation of the great theories of organic chemistry, up to date. An interesting summary is given on Gomberg's work on the so-called trivalent carbon.

HENRY LEFFMANN

THE PETROLEUM HANDBOOK. A practical reference book. By S. O. Andros, A.B., B.Sc., E.M. Chicago, Shaw Publishing Company, 16mo. Price, $2.00. net.

This compact and neatly printed pocket volume contains a large amount of interesting and important information on petroleum, a material now looming more than ever in the world's affairs, and not at all unlikely to become the principal cause of the next great war. The work is divided into eight chapters, covering the following subjects: "Natural History of Petroleum," "Exploration and Drilling," "Preparation for Market," "Natural Gas and Gasoline," "Shale Oil Production," "Marketing of Petroleum and Products," "Legal Regulations," "Economic Applications." The author states that this last chapter contains information not to be found in any other publication.

To the general reader one of the most interesting features is the graphic presentation of the world's production of petroleum and the proportion contributed from different nations. From this we find that in 1917, the United States contributed two-thirds of the total production and Russia stood next with nearly 14 per cent. The production from 1857 to 1917, both inclusive, was nearly 7,000,000,000 barrels of 42 gallons each (a little less than 936 million metric tons), of which nearly 61 per cent. came from the United States and a little over 26 per cent. from Russia. The importance of Russia in the present fuel situation is thus shown. For 1917 the approximate yield in the higher proportions are: United States, 66 per cent.; Russia, 13.6 per cent.; and Mexico, 10.9 per cent. The lower Russian yield is in all probability due to its disordered state. During 1917 the largest yields in the United States were from the Oklahoma and California fields.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. BULLETIN NO. 49. METERING CHARACTERISTICS OF CARBURETORS. 55 pages, illustrations, plates, tables, quarto. Washington, Government Printing Office, 1919.

This report, prepared by Percival S. Tice and H. C. Dickinson, of the Bureau of Standards, presents the results of investigations conducted for the Committee by the Bureau. A description is given of the carburetor testing-equipment constructed by the Bureau of Standards for the convenient and accurate observation of carburetor performances alone, unaffected by engine characteristics. This apparatus permits the testing of carburetors and their elements at widely varying air pressures and temperatures, for both steady and controlled pulsating flow. Fuel quantities are determined by weight and air quantities by an included orifice meter.

Results are given of experiments to determine the effects of varying the diameter, length, and form of entrance of metering passages, as well as of fluidity change with temperature. Under the title "Characteristics of Air Flow in Carburetors," the results of experimental dimensions of the coefficient discharge for various types of carburetor air metering passages are discussed. The next subject considered is the "Effect of Pulsating Air Flow in Carburetors," giving the results of experimental determinations of the effect of pulsating air flow upon the metering characteristics of two carburetors embodying widely different metering methods.

Part V is devoted to a discussion of the theoretical and experimental mixture proportioning characteristics of carburetors as applied to aircraft service, also of the mixture ratios for optimum engine performance. The altitude and throttle compensation characteristics experimentally determined for five carburetors are studied and a new type is shown which possesses nearly complete altimetric compensation. The concluding part of the pamphlet discusses means for securing correct altimetric and throttle compensation. Copies of this Bulletin may be obtained from the Committee.

PUBLICATIONS RECEIVED.

Robison's Manual of Radio Telegraphy and Telephony for the Use of Naval Electricians, by Captain S. S. Robison, U. S. Navy; revised by Captain D. W. Todd, U. S. Navy, and Commander S. C. Hooper, U. S. Navy. 5th edition, revised. 307 pages, illustrations, plates, diagrams, 8vo. Annapolis, Maryland, United States Naval Institute, 1919. Price, $1.50.

Notions Fondamentales de Chimie Organique, par Charles Moureu. 6me edition, revue et considérablement augmentee. 552 pages, 8vo. Paris, Gauthiers-Villars et Cie, 1919. Price, 24 francs.

The Petroleum Handbook, by Stephen O. Andros. 206 pages, illustrations, 16mo. Chicago, Shaw Publishing Company, 1919. Price, $2.00.

U. S. Bureau of Mines: Bulletin 181, Law Serial 19. Abstract of current decisions on mines and mining reported from January to May, 1919, by J. W. Thompson. 175 pages, 8vo. Technical paper 211, approximate quantitative microscopy of pulverized ores, by Will H. Coghill and J. P. Bonardi. 20 pages illustrations, plates, 8vo. Washington, Government Printing Office, 1919.

Statement of Mr. S. A. Thompson, Secretary and Treasurer, National Rivers and Harbors Congress, Washington, D. C. Extracts from hearings before the Committee on Interstate and Foreign Commerce of the House of Representatives, 66th Congress, first session on H. R. 4378. 16 pages, 8vo. Washington, Government Printing Office, 1919.

Patent Policy of a Public Laboratory, by William D. Shoemaker. Reprinted from the Journal of the Patent Office Society for November, 1919. 16 pages, 8vo. Washington, 1919.

Carbo-Coal. ANON. (*Steam*, vol. xxiii, No. 3, p. 62, September, 1919.)—By a new process of low temperature distillation, bituminous coal is treated in such a manner as to recover great quantities of valuable by-products, such as toluol, sulphate of ammonia and valuable oils. From the residue is made a valuable smokeless fuel, of the form of briquettes. Tests of "Carbo-coal" by the Navy disclose that it contains less than 4 per cent. volatile matter, rendering it practically smokeless. Moreover, it is found to work satisfactorily where there is limited grate area and restricted boiler capacity.

R.

CURRENT TOPICS.

New Method of Dehydrating Food. (*Am. Chem. Soc., News Service* No. 249.)—Meats, eggs, vegetables and fruits can now be dried in a manner which preserves their original properties and nutritive value and still have an appearance of freshness when prepared for the table. Although in former years there were dried fruits and vegetables that had a fine appearance, it was often found that they had been treated with sulfites and other materials, the use of which had been questioned by food experts.

Dr. K. George Falk, of the Harriman Research Laboratory, Roosevelt Hospital, New York, N. Y., explained the new methods in an address before the New York Section of the American Chemical Society, of which he is a member. He announced that, following the experimental stage in this process, meats and vegetables had been thoroughly dried in the Industrial Chemistry Laboratory of Columbia University under the supervision of Professor Ralph H. McKee and had been shipped to different parts of the world, where they have been used with success. One consignment of the meat dried in this manner gave great satisfaction in Armenia, where it was distributed by the Near East Relief Fund. Other products of the new dehydration process had been taken to distant parts of the world by exploring parties and had been found to answer all the requirements.

Dr. Falk said that from these meats and other foods which were dried in a vacuum delicious dishes could be made, the taste of which would commend them to any housewife. From the dried meat, savory stews and hashes are made, while the vegetables which may be incorporated with the meat have as fine a flavor as if they had only recently come from the garden.

It would be possible by means of this process to dry beef in vacuum ovens in parts of the earth where cattle may be raised very cheaply, as in Argentina, and to transport the dried product for many thousands of miles at very low freight cost. As canned fruits contain considerable moisture and are placed in metal containers, the advantages of the vacuum-dried products become manifest, according to the view of Dr. Falk.

"Transportation," said he, "has always been a question of vital importance. Ships and other common carriers are always at a premium and again certain kinds of food require special equipment, such as cold storage. For example, the plentiful supply of sheep in New Zealand might benefit the rest of the world to a greater extent if more transportation facilities were available."

Dr. Falk said that usually sun-dried meats and other foods were

discolored and that their nutritive values were impaired. While even with fairly good methods of dehydration it would have been found necessary to use bleaching agents, a recourse which was not required, according to the process developed at the Harriman laboratories. The incentive to develop this method of preservation for food products was given early in November, 1917, by Colonel John R. Murlin, in charge of the Division of Food and Nutrition of the U. S. Army, and was developed by Dr. Falk, Dr. Edward M. Frankel and Professor Ralph H. McKee.

"In the dehydration of meats," said Dr. Falk, "the temperature must be kept below the point at which the proteins coagulate, for if there is too low a temperature the process of dehydration will be unnecessarily prolonged, with the result that often spoilage will occur and the overhead cost will be greatly increased. It is possible to solve this problem of dehydration by the use of a suitable vacuum drier in which the meat or other food product is introduced, in pieces of suitable size, and kept in the vacuum at a temperature which is below that of cooking or which makes no appreciable change."

Dr. Falk said that a large variety of foods had been dehydrated by the vacuum method and that a number of others will probably be subjected in time to the same process. The mechanism used is not complicated and can be easily installed at remote places.

"In considering food preservation methods in general, it may be stated," he said, "that such methods will come into use more and more." The Government estimated that 50 per cent. of the fruits and vegetables grown in this country never reach the consumer as a result of poor transportation facilities, irregularities in marketing or other causes. At the same time, greatly because of recent work on such questions as food hormones, the tendency is to use fresh foods wherever possible. The newer dehydration processes approach more nearly the requisite standards of fresh foods than do the older methods of preservation. The whole question is in a state of development. Dehydration offers the most promising outlook for the future. Air dehydration marks a great advance over the older methods of food preservation, and it would appear that vacuum dehydration possesses in its turn advantages over air dehydration.

Fixed Oils Production in the United States.—The fatty oils are indispensable both in food supply and in many manufacturing industries. They have been the main source of glycerol, which is so important in the explosives industry, though recently it has been shown that the fermentation of carbohydrates yield as a by-product notable quantities. The subject is discussed in Bulletin 769 of the U. S. Department of Agriculture, recently issued. The sum total of the world's supply of fats and oils is less than that of either of the other two types of foods (carbohydrates and proteins), hence a sudden drain is quickly noticed. A great war creates such a drain, since ten tons of fat are required for the

production of one ton of glycerol. The fatty acids, which are the other product, have no food value, but are useful for the manufacture of soap. In England, at the outbreak of the European war, glycerol rose quickly from $250 to $1250 a ton.

In the United States, the use of vegetable oils is increasing. This is due partly to the application of processes for making hard fats from the liquid ones by hydrogenation, and partly to the extending use of the vegetable oils as a substitute for butter. At the outbreak of the war in 1914, Germany was probably the worst prepared country in regard to supply of fats and oils. Preparing, as the nation had been along many lines for self-sustaining, it had overlooked this particular supply, and probably the British blockade hit the enemy harder in this line than in most others. This fact calls attention to the importance of a nation developing its oil supply, and this can be done only through agricultural activity.

In normal times, the United States produces nearly 4,000,000,000 pounds of fats and oils, exclusive of butter-fat, imports over 300,000,000 pounds, exports about 1,000,000,000 pounds and consumes nearly 3,500,000,000 pounds. Including the fat in the butter and cheese made in this country, the total production of fats and oils is about 30,000,000 tons.

H. L.

Fighting Forest Fires by Bombs Impractical. (*U. S. Department of Agriculture, Office of Information.*)—Ingenious persons have recently proposed as a method of fighting forest fires that gas bombs be dropped from airplanes. Officials of the Forest Service say that this suggestion is entirely impractical. There is no analogy between the suggested method and the use of poison gas bombs in fighting, because a fire can not be "poisoned" but must be smothered. Although one part of a poison gas to one million parts of air might be sufficient to kill soldiers, yet 750,000 parts of inert gas to a million parts of air probably would not suffice to put out a fire.

The only kind of a gas which will assist in stopping a fire is an inert one that will neither burn nor support combustion, such as nitrogen or carbon dioxide.

From the standpoint of cheapness and ease in handling, carbon dioxide would probably be the most promising gas, were gas bombs to be experimented with in forest fire fighting. However, as soon as an attempt is made to work out practical plans for such an undertaking, difficulties become apparent. If an airplane carrying 500 pounds of gas bombs containing 300 pounds of carbon dioxide succeeded in dropping the bombs *exactly* on a fire covering some 700 square feet, and if the gas liberated did not escape outside this area or rise more than 10 feet above the ground, such an attack would still be far from effective. The 300

pounds of gas would be equal, in volume, to about 3000 cubic feet, and so the atmosphere surrounding the fire would be about 43 per cent. carbon dioxide and 57 per cent. ordinary air. Since the air contains 21 per cent. oxygen, this mixture would contain 21 per cent. of 57 or 12 per cent. oxygen—enough to support combustion. From such facts Forest Service officials believe that effective use of gas bombs for fire fighting in forests is entirely out of the question.

Work of the United States Bureau of Chemistry for the Last Fiscal Year.—A preliminary report has been issued by this bureau, giving some of the more important work done during the year ending June 30, 1919. The research department was considerably crippled by the assignment of many of its workers to war industries laboratories, but notwithstanding, more prosecutions were brought than in any previous year, and the number of publications by the bureau has also exceeded previous records.

Among the food and drug adulterations that came to notice are enumerated: Slack-filled cans, rotten eggs, fake egg substitutes, butter with excess water, common glue sold as gelatin, adulterated olive oil, frozen oranges, excess of water in canned tomatoes, cacao adulterated with cacao shells. In all 1052 seizures and 843 criminal prosecutions were brought. Of 1019 cases of all kinds reported to the department as terminated in the courts, only three were decided against the government. One line of investigation which occupied much of the time of the inspection force of the bureau was the examination of canned salmon, which included testing the extensive stocks held by the government before allowing it to be sold to the public at large. Much attention has been given to improving the manner of packing and transporting the more perishable foods, in connection with which it has been found that the use of 100-pound boxes for fish is much better than the customary use of barrels. Material improvement in the classification, handling and packing of eggs has been attained. The breakage in railroad transportation has been reduced.

Methods of preserving food so as to carry over a plentiful supply into a period of scarcity has been closely studied, especially the methods of drying vegetables which promises well. A valuable service was rendered in furnishing sugar substitutes for use in the manufacture of soft drinks, and some of these substitutes have proved of such merit that they will probably remain in use.

The prevention of dust explosions in grain elevators and flour mills has been given much study and a marked reduction in this class of disasters has been attained. The bureau reports that corn-cobs, one of the largest waste products of farming, may now be utilized for the preparation of adhesive gum, and a rare sugar, xylose, and processes for converting this into useful mate-

rial have been patented and published. Cull oranges and lemons, not suitable for marketing as fresh fruit, have been made to yield several valuable products, among which are citric acid and marmalade. Work to improve existing methods of extracting starch from cull and surplus potatoes is under way. The influence of the prohibition movement seems to have stimulated the manufacture of barley-sugar or maltose and maltose syrup, and practical studies of the means of using maltose syrup in candy making have been taken up with encouraging results so far.

Many investigations in aid of standard industries have also been carried out. The complete report will be awaited with interest.

H. L.

A Rock-crystal Lens. H. D'A. POWER. (*Camera Craft*, vol. xxvi, No. 11, p. 421, November, 1919.)—Some years ago I had occasion to take a few portraits indoors, exposures that I wished to make instantaneous, and if possible, without the knowledge of the subject. I naturally thought of using one of the modern lenses working at f/3.6 or f/4, but as I already had a Protar working at f/5.6, I did not relish the prospect of expending the very large sum that the larger apertured lens would demand. Just about that time some work had been done in determining the quality of pictures yielded by infra-red and ultra-violet rays; the latter precluding the use of glass through which these rays of great actinic power cannot pass. The concurrence of these two facts suggested the possibility of using a quartz spectacle lens, mounted so as to permit of a very large aperture. By chance I was able to obtain a five-inch spectacle lens of this type with a diameter of one and a quarter inches, this making an aperture of f/4 practically possible. This was fixed in a temporary mount and the first experiment was a satisfactory portrait made in my office with an f/4 stop, and an exposure of one-sixteenth of a second. The subject was placed at least ten feet from a rather high window, and the lighting was that of an average afternoon. Other experiments followed with equally good results, both in portraiture and landscape.

Having unfortunately lost the lens, a second one only produced pictures that were marred by greatly inferior definition. I later found that crystal or pebble lenses, as they are called in the trade, had passed out of use on account of the frequency of structural defects in the material. But recently on attending a meeting of the State Medical Society, I was shown a number of very beautifully made crystal lenses used in the transmission of violet rays for therapeutical purposes. I inquired of the agent, representing the Hanovia Chemical and Manufacturing Company of Newark, New Jersey, as to whether or not a spectacle lens could be made for me that would be structurally flawless and was assured that it could be done. In due time a four and a half-

inch focus lens with an aperture of one and one-half inches came to hand. The results obtained by this lens were most satisfactory and it seems to me there is much to be said in favor of a very general use of lenses of this type.

It will be recollected by photographers of artistic tendencies that some years ago Major Puyo and other members of the Paris Photo Club started a movement for the use of spectacle lenses of large size, claiming for them the production of better balanced images, devoid of the harshness of the anastigmat and therefore having a plasticity of modeling that is absent from most photographs. It is an outgrowth of this movement that has given us the soft focus lens that is now so much in favor, but the good soft focus lens is a costly apparatus; ordinary spectacle lenses or, to use the correct term, simple non-achromatic lenses, have certain good and bad points. Among the former the ability to transmit a larger amount of light, owing to the absence of reflection from many surfaces, and great cheapness. Against these are to be placed linear distortion, which makes straight lines near the edges of the plate appear curved, and difference of focus between the image seen and the image recorded on the plate, which last can be overcome only by racking back after focusing.

When, however, a simple lens is made of rock crystal, this graver defect is so reduced as to be of no importance, for, whereas the difference between the visual and actinic of a glass lens is as much as one-fortieth of the focal length, the difference in the case of the rock-crystal lens is less than one-four hundredth, and this is insufficient to make any real difference in focusing necessary. The form of the lens should be that of a meniscus with the convex surface turned toward the plate. The diaphragm should be placed well in advance of the lens at a distance of about one-fourth of the focal length and a lens shade should be employed, practically when working at full aperture.

Humanity of Poisonous Gas. LIEUT. COL. AMOS A. FRIES, Corps of Engineers, Chemical Warfare Service, U. S. Army, formerly Brig. Gen. and Chief of the Chemical Warfare Service in the American Expeditionary Forces, France. (*Chemical Warfare*, vol. i, Nos. 11 and 12, 1919.)—The first gas attack was made by the Germans at Ypres with chlorine in 1915; the resulting death-rate was probably 35 per cent. During the last year of the war the death-rate from gassing fell to 2.5 per cent. in the British army, despite an enormous increase in the number of gas casualties—cases of gassing requiring medical treatment. Thus the number of gas casualties per month increased during the last sixteen months of the war to 14 times the number during the preceding year. The reduction in the death-rate was due to development of masks and other methods of protection. The statistics of the Surgeon General's office, U. S. Army, covering all cases of battle

casualties reported up to September 1, 1919, show that 23.4 per cent. of all casualties from bullets and high explosives and 1.87 per cent. of all casualties from gas resulted in death. Often a man injured by gas had 12 times as many chances of recovery as had one wounded by bullets or high explosives. Gassing did not predispose to tuberculosis nor open up old tubercular lesions. The death-rate is reduced solely by the gas-mask and training in its use. As new gases are introduced, the mask must be improved to protect against them.

Experiments with poison gases can be carried out with perfect safety in the laboratory, and on a large scale in the open. Light winds carry away all poison gases except mustard gas almost instantly in the open. While gases persist longest in woods at night in warm weather, yet they become so diffused that they are no longer dangerous after four to six hours; this period is reduced to one or two hours by wind and sunshine. Mustard gas may give off poisonous vapor for two days in warm dry weather, and for possibly two weeks in cold damp weather; but the vapor is carried only a short distance by the wind. Poisonous gases may be kept in suitable containers, including shells, for at least a year.

Irritating gases irritate the nose and throat. Lachrymatory gases produce a flow of tears. Both types of gas require wearing of a gas-mask when present in concentrations of 1 in 10,000,000, and thereby reduce the efficiency of combatant troops by 25 to 75 per cent. Gas is an excellent means of eradicating snipers. Cloud gas and that fired from mortars and projectors has a short range, about 1.5 miles. Beyond that range, the gas was fired in artillery shells. Gas warfare is humane and a great insurance to the safety of the United States.

J. S. H.

Graphite Production.—*Bull. 10, U. S. Geol. Sur.*, compiled by H. G. FERGUSON, gives information as to the amount of graphite mined in the United States during 1918. The material occurs in nature in two forms, crystalline and amorphous and each form has its special uses. The term "crystalline" or "flake" graphite is generally understood to mean specimens in which the crystalline nature is visible to the unassisted eye, and, of course, much of the so-called "amorphous" material will show crystals under the microscope. Crystalline graphite occurs in veins or distributed in flakes through the rocks; amorphous graphite may occur wherever coal or other carbonaceous deposits have been altered by the action of igneous rocks or movements within the earth's crust.

The bulletin separates the production of the two forms. The total production of crystalline graphite in 1918 was nearly 6500 short tons valued at about $225 per ton; the production of amor-

phous graphite in the same period was about the same in quantity, but the value was much less. The bulk of the crystalline graphite came from three states: Alabama, which yielded about 60 per cent.; New York, which yielded nearly 30 per cent., and Pennsylvania, about 10 per cent.

Artificial graphite, now a well-known product, is manufactured principally by the Acheson Graphite Company from power at Niagara. The output has increased greatly in recent years, and now forms an important item in the domestic supply. It is suitable for all the purposes of the natural graphite except the manufacture of large crucibles, but, on the other hand, it is more suitable for the manufacture of electrodes which are in great demand and which are not now made from the natural mineral. The production of artificial graphite for purposes in which it competes with the natural material, by the Acheson Company, rose from about five million pounds in 1915 to nearly ten million and a half in 1917, and was somewhat over nine million pounds in 1918. A small quantity of high-grade graphite has been obtained by H. Schmehl, at Chester Springs, Pa., from old crucibles.

H. L.

Trinitrotoluene Poisoning.—The extensive use of this explosive, commonly termed T.N.T., has drawn attention to its sanitary relations. It is, as might be expected, highly poisonous, whether taken directly or inhaled as dust. An investigation conducted by Messrs. Voegtlin, Hooper and Johnson, of the Hygienic Laboratory of the U. S. P. H. S. is published as Reprint 534 of that department. It was found that different species of animals exhibit marked differences in susceptibility to the substance. Dogs and cats (probably also human beings) are much more susceptible than white rats, guinea-pigs, and rabbits. The symptoms generally presented are cyanosis, bowel disturbance, jaundice and anæmia. The condition is not constant, as cyanosis, which usually appears at the beginning of the poisoning may disappear later. While true immunity is not developed, it appears that dogs (which were mostly used in the experiments) do not suffer such severe symptoms in the later stages of the poisoning. The poison is principally eliminated through the kidneys, but not in unchanged form. Dogs fed on meat seem to have a greater resistance to the substance than when given only white bread and milk.

Several methods of protection for workmen were tried. It was found that a varnish composed of 1 part shellac, 1 part of castor oil, and 24 parts of 95 per cent. alcohol could be used with satisfaction, as when applied to the skin of the hands and arms it dries to a protective film that does not peel off but can readily be removed by alcohol. A modification of this formula has been used for impregnating cotton gloves, by which they are rendered

efficient protectors. At the suggestion of Dr. Alice Hamilton, a number of solvents were tested to determine their capacity to remove the poison from the skin. It was found that a 10 per cent. solution of sodium hydrosulphite is the best of those tried; the next best is sodium sulphite solution. It appears that a certain percentage of workers are abnormally susceptible, due generally to a very permeable skin. These should be eliminated from the factory. The skin penetration is the most usual method of introduction of the poison, hence skin protection is especially enjoined, but inhalation is also not to be overlooked, and this must be met by free ventilation. The American investigators, however, did not find skin absorption to be as promising a method of infection as did the British investigators. A decrease of hæmoglobin is noticed early in the poisoning, and the investigators recommend a supervision over the workers by means of blood tests. It would seem that some simple form of gas-mask could be used to control the inhalation danger.

H. L.

Coal Mining Fatalities in the United States.—That coal mining is one of the most important industries of this country has been brought home to every citizen during the past few years. The amount of coal produced now approaches closely to 700,000,000 tons yearly, employing about 760,000 men. That it is a laborious and dangerous occupation is well established by the statistics of death and injury published from time to time. A bulletin prepared by A. H. Fay has just been issued by the Bureau of Mines, giving the fatalities in the coal mines of the United States during 1918. This was a year of somewhat abnormal conditions. The demand for coal was much increased over that of previous years, many of the expert miners and supervisors had enlisted or entered into more profitable industries, and a not inconsiderable number were drafted. This naturally made for a greater proportion of accidents as many comparatively inexpert men were employed, but, on the other hand, the more continuous operation of the mines prevented accumulation of gases and in some other ways improved conditions as compared with mines operated only part time. The total fatalities reported, including all fuel mining during the year was 2579. The non-fatal injuries are not given in the bulletin, but taking Pennsylvania statistics as a guide, it may be estimated that these amount to at least three times the fatal accidents, so that the total for the United States will be about ten thousand casualties for the year. There is still to be counted as part of the perils of the industry the disease and debilitation produced, especially the liability to tuberculosis, and in some mines to hook-worm. No data on these points are at hand and no estimate can be made, but there is little doubt that the morbidity percentage will be fairly high. Pennsylvania being the

only state in which any considerable anthracite mining is carried on, it is interesting to note that in 1916 the fatalities and non-fatal accidents in that industry were much higher than in the bitumionus mines of the state. The figures show that 1 life was lost for 155,000 tons of anthracite mined, and 1 life for 388,000 tons of bituminous coal. The non-fatal accidents were also of higher ratio in the hard coal mines. Part of this difference may be due to the depth at which anthracite is now generally mined. In Pennsylvania in 1916 the fatalities left 631 widows and 1510 orphans. Taking the United States at large for 1918 the production of coal of all kinds per life lost was 266,000 tons, an improvement over 1917, in which the production per fatality was 241,000 tons. The days worked in 1917 were 251, and somewhat higher in 1918.

H. L.

Manganese in New Mexico. (*U. S. Geol. Sur. Bull. 710-B.*)—This bulletin, prepared by E. L. Jones, Jr., presents the data in regard to the efforts made during the war to secure manganese from the New Mexico deposits. These are scattered mostly along the Rio Grande, west of the central line of the state, and occur in both sedimentary and igneous rocks. Both oxides and primary minerals are found but only the former are mined. A limited use of the ores has been made for many years, but the great increase in price of manganese brought about by the war, led to much more extensive operation of known mines and active search for new deposits. The total production to December 1, 1918, was 5500 tons. A few deposits are capable of yielding several thousand tons, but most are of small size. The ore has to be shipped to points east of the Mississippi, which involves a high freight rate. The minimum rate to Chicago was $8 per short ton, in addition to which the charges for mining and wagon transportation to the railroad siding were high, so that even with the high prices prevailing during 1918, little profit was made, and with return of pre-war prices, probably none of the deposits can be worked profitably.

H. L.

Gold-lode Mining in Alaska. (*U. S. Geol. Surv., Press Bulletin,* November, 1919.)—Twenty-five gold-lode mines were operated in Alaska in 1918, according to the U. S. Geological Survey, Department of the Interior. There was also a production from seven prospects—abandoned mines or small mines that were not in regular operation. The value of the lode-gold output decreased from $4,581,453 in 1917 to $3,473,317 in 1918, owing partly to the disaster at the Treadwell mine in April, 1917, and partly to curtailment of operations, especially in the Juneau district, because of shortage of labor. Southeastern Alaska, especially the Juneau district, is still the only centre of large quartz-mining operations in the territory. Next in importance is the Willow Creek lode

district. The production in the Fairbanks district decreased materially, as the lode-mine owners of Fairbanks are still awaiting the cheapening of operating costs, especially of fuel, which is expected on the completion of the Government railroad. In 1918 the average value of the gold and silver contents for all siliceous ores mined was $1.70 a ton; the average for 1917 was $1.37 a ton. These averages reflect the dominance in the total lode production of the large tonnage produced from the low-grade ores of the Juneau district.

Studies in Catalysis.—From pamphlets issued as reports of a symposium on catalysis, held at the thirty-sixth general meeting (September, 1919) of the American Electro-Chemical Society, some very interesting data are taken. The word "catalysis" was coined by Berzelius in 1836, but one of the most striking instances of the effect had been made known by Doebereiner four years previously, namely, the effect of manganese dioxide in promoting the decomposition of potassium chlorate. The subject of catalysis in the inorganic field has become of great importance of late years, owing to valuable applications in industries, such as the manufacture of sulphuric acid, ammonia and the hydrogenation of oils. One of the contributors to the symposium, Hugh S. Taylor, states that a striking physical feature common to the catalysis agents is that they are mainly porous or finely divided materials. For example, bog iron ore, a light porous ferric hydrate, is an agent in the oxidation of hydrogen sulphide to sulphur in purifying illuminating gas. Cuprous chloride distributed over a porous mass, such as fire-brick, is used in the Deacon chlorine recovery process. Platinum deposited on asbestos or magnesium sulphate, is used in the sulphuric acid manufacture. Porous, reduced, iron-molybdenum is used in ammonia synthesis, the massive alloy is inert. Porous bodies have, as a rule, high adsorptive powers, but the two properties are not necessarily correlative. Patrick, of Johns Hopkins, has found that a silica gel that he prepared is highly adsorptive, but not so far as known, catalytic. Taylor passes on to the consideration of the so-called "poisons" of catalysts, that is, the substances which in small amount deprive the catalyst of activity. His investigations lead him to the view that the effect is due to a slowing down of the velocity of the adsorption of the reacting substances. The value, therefore, of the clean surface is evident. Experiments have recently shown that "clean" charcoals are much more efficient in the gas-mask. One actual measurement of relative action has been made by Dr. Harned (U. of Pa.), who obtained contrasting results from two portions of charcoal, one of which had been cleaned by successive washings with chlor-picrin and the other simply evacuated. Curves plotted from the data show that the adsorption by the clean charcoal was much more rapid than with the uncleaned sample, but that it is evident that in an indefinitely long interval the effect of

both adsorbents will be equal. In the first five-minute intervals in an experiment, the adsorption of the cleaned charcoal was 500 times greater than with the uncleaned, it may be assumed that in a still briefer interval the difference will be much greater.

A further interesting feature is that admixture of small amounts of substances, perhaps not in themselves catalytic, will activate strongly a true catalyst. The action of the small amount of cerium oxide on thorium oxide in the gas mantle is well known, and it is found that a mixture of 0.5 per cent. of cerium dioxide with iron oxide gives a catalyst many times more reactive than the iron oxide alone. The term "promoters" has been given to substances of this activating class, but although a large amount of investigation has been given to the topic, the nature of the action is unknown. Undoubtedly, most valuable practical results will flow from extended researches in this line.

H. L.

Fog Signal System. ANON. (*The Marine Review*, vol. l, No. 1, p. 17, January, 1920.)—In coöperation with the Bureau of Lighthouses, experiments are being carried on by the Bureau of Standards to establish a radio fog signaling system. Such a system, when perfected, will give the navigator a reliable signal under any conditions of fog and make him independent of the lighthouse lamp. The principal object to be sought is the sending out of a radio signal automatically from a lighthouse and the reception of this signal upon a ship by a simple radio direction finder. If a number of important lighthouses on the Atlantic coast are equipped with this system, the safety of navigation will be greatly advanced. In connection with these experiments, radio transmitting apparatus is being placed at three lighthouses in Chesapeake Bay and the radio receiving apparatus and direction finder installed on a lighthouse tender. Three lighthouses are used, so as to give comparative information on different types of modern transmitting equipment and to determine which is the best suited for this work. The apparatus is of special type developed by the Bureau as a result of some of its researches on radio problems during the war.

R.

A 24-Hour Clock at Waterloo Station, London. ANON. (*Railway Age*, vol. lxvii, No. 24, p. 1171, December 12, 1919.)—Considerable interest is now being taken in England in the idea of timing trains on the 24-hour system. This method is general on the Continent, and is regarded as having the important advantage of rendering more clear the actual arrival and departure time of trains. Difficulties with regard to A.M. and P.M. are altogether surmounted, and on long-distance bookings it is a very simple matter to ascertain whether one will get to any point during the day or in the night. With this in mind, a 24-hour clock has recently been installed at

the Waterloo station of the London and Southwestern Railway, London, with a view to putting English "timings" into line with Continental. The clock has the usual dial with Roman numerals, the figures 13 to 24 being placed in smaller Arabic numerals inside, opposite their respective Roman numerals. Most of the time-tables of Continental bookings printed in England now use the 24-hour system.

R.

New Bearing Metal. ANON. (*Machinery,* vol. xxvi, No. 4, p. 329, December, 1919.)—A development in bearing metal which is the outgrowth of the scarcity of tin during the war was of great value to the Government during the period of hostilities. It is an electrically hardened lead with a very small percentage of other ingredients added which had never before been used in bearing metals. The Bureau of Standards made a series of tests on this new bearing metal and issued a report showing that the tensile strength of the metal is 13,000 pounds, the elastic limit 11,525 pounds, and that it is capable of enduring a running test at a pressure of 1000 pounds per square inch at a speed of 400 revolutions per minute. The final temperature was only 150 degrees F. The report stated that this metal possesses all the requisites of a good bearing metal, that is, hardness, compressive strength, low friction, and heat resistance, as well as low cost.

R.

Gas-Masks for Industrial Use. ANON. (*The India Rubber World,* vol. lxi, No. 2, p. 103, November 1, 1919.)—The gas-mask is rapidly finding its proper place in the industries. Experience has shown that it has a wide application in protecting workmen from the noxious gases and fumes given off in many chemical operations. In rubber factories gas-masks could be used around volatile solvents, such as carbon disulphide, carbon tetrachloride, sulphur chloride and certain organic accelerators. In allied chemical plants they give good protection in pyrite smelting and roasting operations wherever sulphur dioxide or oxides of nitrogen are encountered. The war gave great impetus to the development of better gas-masks, and now the Bureau of Mines has established a gas-mask department at the Pittsburgh Experiment Station, where masks of the army type will be developed for industrial use.

R.

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